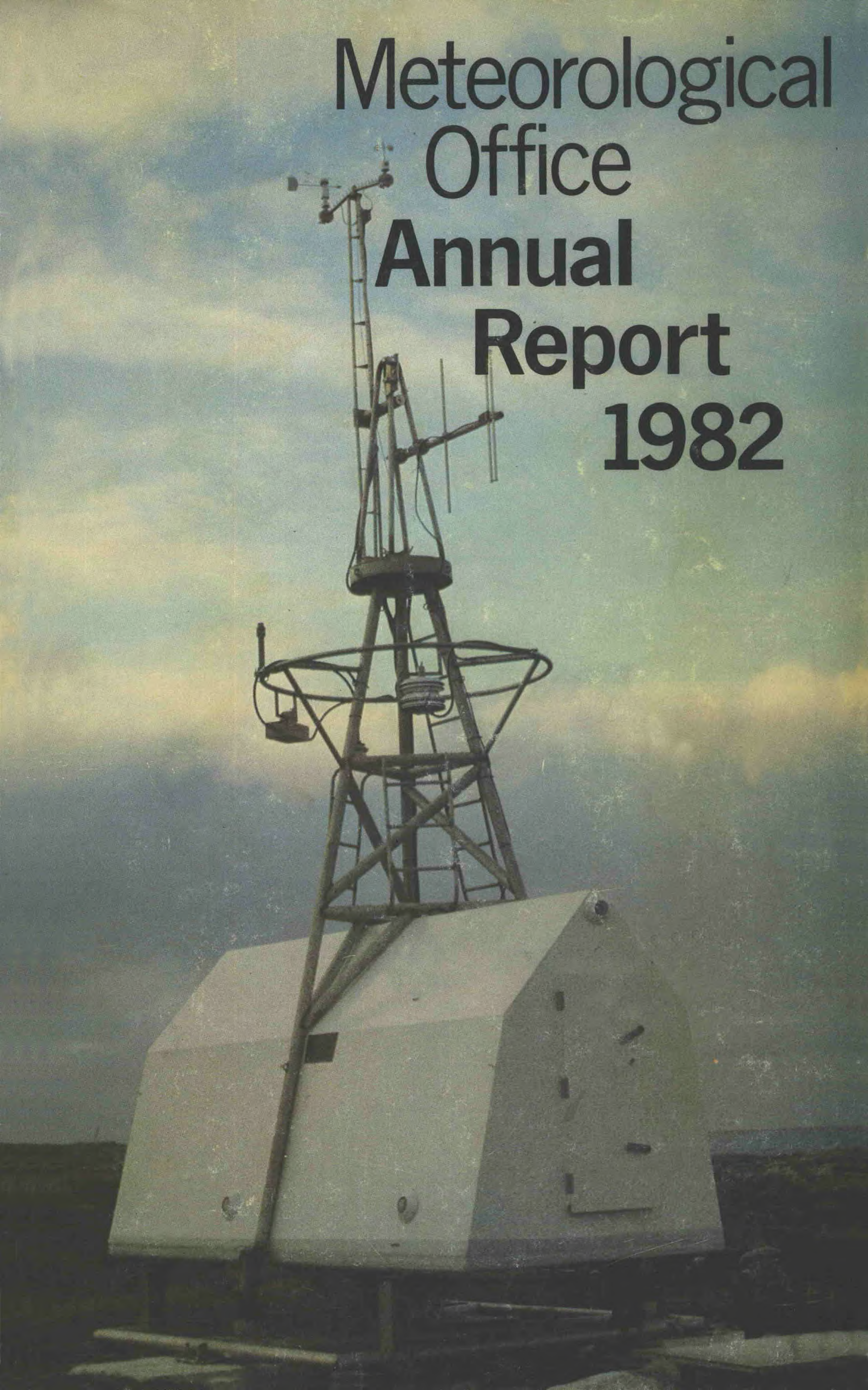
Meteorological Office Annual Report 1982



Met. O. 961

ANNUAL REPORT
ON THE
METEOROLOGICAL OFFICE
1982

Presented by the Director-General
to the
Secretary of State for Defence

LONDON
HER MAJESTY'S STATIONERY OFFICE

U.D.C.
551.5(058)

First published 1983

ISBN 0 11 400345 9

Cover photograph: Sule Skerry Automatic Weather Station, September 1981.
Photograph taken by Mr M. J. Kerley.

FOREWORD BY THE DIRECTOR-GENERAL

During the last year much effort has been devoted to developing a new operational weather forecasting model and its associated data-assimilation scheme for use on the new CYBER 205 computer. The new model has 15 levels, is global in coverage, and has roughly twice the horizontal resolving power of the 10-level hemispheric model which it replaces. The main meteorological parameters are computed every 15 minutes at more than one-third of a million grid points but such is the speed of the new computer (about 400 million operations per second) that a 24-hour forecast for the whole earth is computed in less than four minutes. This global model became fully operational in early September and right away produced forecasts of unrivalled quality up to five days ahead. A finer-mesh version of the model, again with 15 levels and covering Europe and the North Atlantic Ocean on a 75 km (or 50 km) horizontal grid, is being developed to predict the weather, and especially rainfall, in more detail at 6-hour intervals up to 36 hours ahead. This is expected to become fully operational in early 1983.

These models, together with our unrivalled computing power, were major factors in the decision by the Council of the International Civil Aviation Organization to select Bracknell as one of the two World Forecasting Centres for civil aviation. Bracknell and Washington will each provide global forecasts of winds and temperatures for flight planning by all the world's airlines. In fact, Bracknell has supplied such information to British Airways and the Scandinavian Airlines System by direct computer-to-computer link since mid-June and the service will be available to other airlines in 1983. Bracknell and London/Heathrow Airport will also continue to act jointly as an Area Forecast Centre providing detailed weather forecasts and documentation for all airliners flying from Europe to anywhere in North America.

The demand for meteorological services in support of Defence increased considerably as a result of the Falklands conflict. Many Branches of the Office were called upon to meet a wide variety of requirements and staff volunteered to work long hours, often at short notice. A major programming effort over the weekend of 3–4 April allowed the Office to produce, for the first time, forecasts up to three days ahead for the southern hemisphere with special attention given to the area of military operations. These were available from 4 April—four months ahead of the planned introduction of the new global model. Additional staff, mainly scientists from the Research Branches, were transferred to the Central Forecasting Office so that a special forecasting unit for the Falklands Operations could be introduced. Because of the scarcity of conventional observations maximum use was made of satellite data. Close working relations were quickly established with the RAF and the Royal Navy who have been very generous in their praise of our efforts. The first Mobile Meteorological Unit manned by our staff was deployed in Ascension Island as a 'stand alone' unit on 8 April and a second unit has operated in the Falkland Islands since 13 July.

The need to reduce the number of staff providing meteorological services to the RAF has been the subject of a joint study by the Air Staff and the Office. Main Meteorological Offices at Rheindahlen and Innsworth have been closed and significant staff savings made elsewhere. A computer system, linked directly to the Bracknell installation, was brought into operation at the Principal Forecasting Office at HQ RAF Strike Command in January with substantial savings in staff. Pilot projects whereby outstation forecasters will be able to call up on demand radar, satellite and conventional data on a colour graphics display from a central computer are under way.

Revenue-earning services carried out for industry, commerce and the media continued to grow and produced 28 per cent more income than last year. The biggest growth areas have been forecast services supplied to the offshore industry and to television where considerable additional revenue is expected from 'breakfast' television. The total number of non-aviation enquiries reached 1 838 079 and the number of calls made on the Automatic Telephone Weather Service (Weatherline) was 25 510 988.

The IBM 360/195, one of the fastest computers in the world in its day, was finally closed down in December after 12 years of excellent service during which it operated 24 hours a day and for over 98 per cent of the total time. It was replaced, within 10 hours, by an IBM 3081 computer which will act as a 'front end' to the CYBER 205 and undertake many of the tasks that do not require the great speed and special properties of the main machine.

The last two of our Ocean Weather Ships, built in 1944 as Castle Class frigates, were scrapped early in the year and the Base at Greenock was closed. We now have only one ship, a chartered converted trawler, which operates alternately with a Dutch weather ship on one of the four North Atlantic stations. The other stations are manned by France, Norway and Sweden jointly, and the USSR, but Sweden has recently signified its withdrawal at the end of 1983 and the future of the whole system is a matter for real concern. This is only one aspect of a wider threat to the integrity of the global weather observing system which has been built up gradually over many years. Because of political and economic problems the system is deteriorating in many parts of the world. Unless these basic observing systems and their associated telecommunications can be sustained or partly replaced by satellite systems (and the future of even the present satellite system is by no means guaranteed), much of the considerable improvement in the accuracy and range of weather forecasts achieved in recent years will be lost and further significant progress will be impossible. This is by far the most serious problem facing the international meteorological community; more complex and ingenious numerical models and more powerful computers will not produce better forecasts without an adequate input of observations.

From the research activities I have chosen the following items for particular mention this year in addition to the Special Topic on Carbon Dioxide and Climate.

In the latest of a series of field experiments designed to study the effect of hills on the low-level airflow, a major operation was mounted in September–October on and around an isolated hill, Blashaval, in North Uist. Arrays of improved instruments placed at different heights both on and upstream of the hill provided measurements of the mean airflow, the temperature distribution and near-surface turbulence, which should help discriminate between the various conflicting theories of airflow over isolated hills.

Results emerging from the large international joint Air–Sea Interaction Experiment (JASIN) conducted in the North Atlantic in September 1978 are described in some detail in this report and were presented at a Royal Society meeting in June. Transfer processes at the air–sea interface were measured by a variety of techniques from 14 ships, 3 aircraft, several buoys and by microwave remote sensing instruments on the SEASAT A satellite. The agreement obtained between the satellite and more conventional techniques was especially gratifying and enabled the variations in the sea-surface fluxes of heat, water vapour and momentum to be examined in relation to the synoptic-scale weather systems. This improved knowledge will be of value in designing numerical models of the atmosphere for both weather forecasting and studies of climatic variations.

Our Stratospheric Sounding Units (SSU) flying on US polar-orbiting satellites continued to provide exciting and unique data. As a result of careful instrument calibration it has been possible to detect and make detailed studies of solar tides in the stratosphere as well as the lunar tides reported last year. The SSU data, which also provide long-term monitoring of changes in the global mean temperature, confirmed a significant warming of the lower stratosphere, probably caused by dust clouds from the Mexican volcano.

Considerable progress was made in the development of a new 11-level model of the global atmosphere which will be run over many annual cycles on the CYBER 205 computer both to simulate the present-day world climate, its regional and seasonal changes, and also to extend our investigations on the mechanisms of climatic changes, both natural and man-made. It is becoming increasingly clear that such changes cannot be properly simulated, much less predicted, unless the models actually predict changes in cloud cover rather than have this prescribed by average climatological values. Encouraging progress has been made with this very difficult problem but some discrepancies remain especially in polar and mountainous areas. It is also probable that longer-term climatic changes are greatly influenced by interactions between the atmosphere the oceans and the polar ice masses. We are therefore developing a series of ocean models of increasing complexity together with a sea-ice model which, when coupled to the atmospheric model, are expected to reproduce a realistic seasonal cycle of sea-surface temperatures.

Meanwhile we have just completed the most detailed study so far of the climatic consequences of increasing the carbon dioxide content of the atmosphere by 2, 4 and 10 times the present value. There are strong indications that both the changes in the global average temperature and rainfall and the uneven geographical distribution of such changes depend very much on how much of the increased heat flux at the earth's surface produced by the additional carbon dioxide is stored and transported by the oceans and on the consequent changes in sea-surface temperature.

After eighteen years during which I have been Director-General, this is likely to be my last report. It has been a great privilege and pleasure to have been a part, for so long, of what I am confident is the most advanced, professional, dedicated, enthusiastic and efficient meteorological service in the world. May it go from strength to strength!

B. J. MASON

January 1983
Meteorological Office
Bracknell, Berks.

CONTENTS

	Page
FOREWORD BY THE DIRECTOR-GENERAL	iii
FUNCTIONS OF THE METEOROLOGICAL OFFICE	vii
METEOROLOGICAL COMMITTEE	viii
PRINCIPAL OFFICERS OF THE METEOROLOGICAL OFFICE	ix
METEOROLOGICAL OFFICE ORGANIZATION	xii
DIRECTORATE OF SERVICES	
Special topic—The Central Forecasting Office	1
Forecasting services	15
Climatological services	31
Services for hydrometeorology	35
Services for agriculture	38
Observational requirements and practices	41
Operational instrumentation	48
Computing and data processing	53
Systems development	56
Meteorological telecommunications	58
International and planning	62
Statistics	66
DIRECTORATE OF RESEARCH	
Special topic—Carbon dioxide and climate	75
Physical research	90
Dynamical and synoptic research	105
Library, Editing, Publications, Archives and Cartography	124
Professional training	125
General activities of the Research Directorate	127
Statistics	128
ADMINISTRATION	
Personnel management	132
Equipment	134
Finance (financial year 1981/82)	134
STAFF HONOURS AND DISTINCTIONS	139

APPENDICES

	Page
I. BOOKS OR PAPERS BY MEMBERS OF THE STAFF	140
II. A SELECTION OF LECTURES AND BROADCASTS GIVEN BY MEMBERS OF THE STAFF	147
III. INTERNATIONAL MEETINGS ATTENDED BY MEMBERS OF THE STAFF	156
IV. PUBLICATIONS	165
V. ACRONYMS AND ABBREVIATIONS	167

FUNCTIONS OF
THE METEOROLOGICAL OFFICE

The Meteorological Office is the State Meteorological Service. It forms part of the Ministry of Defence and is administered by the Air Force Department. The Director-General is responsible to the Secretary of State for Defence through the Parliamentary Under-Secretary of State for Defence for the Armed Forces.

The general functions of the Meteorological Office are:

(a) The provision of meteorological services for the Army, Royal Air Force, civil aviation, the merchant navy and fishing fleets; provision of basic meteorological information for use by the Royal Navy; and liaison with the Director of Naval Oceanography and Meteorology.

(b) The provision of meteorological services to other government departments, public corporations, local authorities, the Press, television, radio, industry and the general public.

(c) The organization of meteorological observations, including observations of radiation, atmospheric electricity and ozone, in the United Kingdom and at certain stations overseas.

(d) The collection, distribution and publication of meteorological information from all parts of the world.

(e) The maintenance of the observatory at Lerwick.

(f) The provision of professional training in meteorology.

(g) Research in meteorology and geophysics.

The Meteorological Office also takes a leading part in international co-operation in meteorology. The Director-General is the Permanent Representative of the United Kingdom with the World Meteorological Organization, and acts in concert with the other Directors of the Meteorological Services in western Europe in the co-ordination of their programs.

METEOROLOGICAL COMMITTEE

Terms of reference:

(a) To keep under review the progress and efficiency of the meteorological service and the broad lines of its current and future policy.
(b) To keep under review the general scale of effort and expenditure devoted to meteorological services and research.
(c) To ensure the maintenance of adequate contact between the Meteorological Office and those who use its services.

Membership as at 31 December 1982:

Chairman: The Earl of Halsbury, F.R.S., succeeded by Sir Peter Swinnerton-Dyer, Bt, F.R.S. in July 1982

Members: Professor A. H. Bunting, C.M.G.
Professor H. Charnock, F.R.S.
Professor P. H. Fowler, D.Sc., F.R.S.
Mr J. Miller, F.I.O.B.
Mr J. McHugh
Mr G. Williams
*Sir John Mason, C.B., F.R.S. (Director-General, Meteorological Office)
*Mr D. C. Humphreys, C.M.G. (Deputy Under-Secretary of State (Air))
*Air Vice-Marshal K. W. Hayr (Assistant Chief of the Air Staff (Operations)); alternate, Group Captain M. J. C. Burton
*Captain D. C. Blacker, B.Sc., R.N. (Director of Naval Oceanography and Meteorology)
*Mr A. White (Representative Civil Aviation Authority); alternate for research meetings, Mr J. C. Morrall

Secretary: *Mr F. R. Howell, M.B.E., F.C.I.S. (Secretary, Meteorological Office)

**ex officio*

The Committee met four times in 1982. One quarterly meeting was devoted to the research program.

PRINCIPAL OFFICERS OF THE METEOROLOGICAL OFFICE

DIRECTOR-GENERAL

Sir John Mason, C.B., D.Sc., F.R.S.

DEPUTY TO THE DIRECTOR-GENERAL

F. H. Bushby, B.Sc., A.R.C.S.

DIRECTORATE OF SERVICES

DIRECTOR	F. H. Bushby, B.Sc., A.R.C.S.
International and Planning Assistant Director	G. J. Day, B.Sc.

FORECASTING SERVICES

DEPUTY DIRECTOR	D. H. Johnson, M.Sc., D.I.C., A.R.C.S.
Central Forecasting Assistant Director	C. R. Flood, M.A.
Defence Services Assistant Director	I. J. W. Pothecary, B.Sc., M.Inst.P.
Chief Meteorological Officer, H.Q. Strike Command	A. G. Forsdyke, B.Sc.
Public Services Assistant Director	R. M. Morris, B.Sc.
Chief Meteorological Officer London/Heathrow Airport	K. Bryant

COMMUNICATIONS AND COMPUTING

DEPUTY DIRECTOR	M. J. Blackwell, M.A.
Telecommunications Assistant Director	A. I. Johnson, B.Sc., A.R.C.S.
Data Processing Assistant Director	P. Graystone, B.A.
Systems Development Assistant Director	P. Ryder, Ph.D.

OBSERVATIONAL SERVICES

DEPUTY DIRECTOR	D. N. Axford, Ph.D., C. Eng., M.I.E.E.
Observational Requirements and Practices	
Assistant Director	J. M. Nicholls, B.Sc.
Marine Superintendent	G. A. White, Captain, Extra Master
Climatological Services	
Assistant Director	F. Singleton, B.Sc., D.I.C.
Agriculture and Hydrometeorology	
Assistant Director	C. V. Smith, M.A., B.Sc.
Operational Instrumentation	
Assistant Director	R. E. W. Pettifer, Ph.D.

DIRECTORATE OF RESEARCH

DIRECTOR	P. Goldsmith, M.A.

PHYSICAL RESEARCH

DEPUTY DIRECTOR	D. E. Miller, B.A.
Geophysical Fluid Dynamics Laboratory	
Head of Branch	R. Hide, Sc.D., F.R.S.
Boundary Layer Research	
Assistant Director	D. J. Carson, Ph.D.
Special Post	F. B. Smith, Ph.D.
Meteorological Research Flight	
Chief Meteorological Officer	C. J. Readings, Ph.D., D.I.C., A.R.C.S.
Meteorological Office Radar Research Laboratory	
Chief Meteorological Officer	K. A. Browning, Ph.D., D.I.C., F.R.S.
Meteorological Office Cardington	
Special Post	P. J. Mason, Ph.D.
Cloud Physics	
Assistant Director	P. R. Jonas, Ph.D., D.I.C.
Special Post	A. F. Tuck, Ph.D.
Satellite Meteorology	
Assistant Director	R. L. Wiley, Ph.D.

DEPUTY DIRECTOR	A. Gilchrist, M.A.
SPECIAL INVESTIGATIONS Assistant Director	W. T. Roach, Ph.D., D.I.C.
FORECASTING RESEARCH Assistant Director	P. W. White, Ph.D.
SYNOPTIC CLIMATOLOGY Assistant Director	D. E. Jones, M.Sc., D.I.C., A.R.C.S
PROFESSIONAL TRAINING Assistant Director and Principal, Meteorological Office College	S. G. Cornford, M.Sc.
DYNAMICAL CLIMATOLOGY Assistant Director Climate Modelling	 A. J. Gadd, Ph.D. P. R. Rowntree, Ph.D.

ADMINISTRATION, FINANCE AND SUPPLY

SECRETARY, METEOROLOGICAL OFFICE	F. R. Howell, M.B.E., F.C.I.S.
PERSONNEL MANAGEMENT Assistant Director	D. M. Houghton, M.Sc., D.I.C.

METEOROLOGICAL OFFICE ORGANIZATION

(at 31 December 1982)

- Director-General
  - Director of Research
    - Deputy Director (Physical Research)
      - Met O 14 (Boundary Layer Research)
      - Met O 15 (Cloud Physics)
      - Met O 19 (Satellite Meteorology)
      - Met O 21 (Geophysical Fluid Dynamics)
      - Meteorological Research Flight
      - Radar Research Laboratory
    - Deputy Director (Dynamical Research)
      - Met O 9 (Special Investigations)
      - Met O 11 (Forecasting Research)
      - Met O 13 (Synoptic Climatology)
      - Met O 18 (Library, Publications, Editing, Archives, Cartography)
      - Met O 20 (Dynamical Climatology)
      - Met O College (Professional Training)
  - Secretary
    - Met O 4 (Supply, Finance, Secretariat, Office Services)
    - Met O 10 (Personnel Management)
  - Director of Services
    - Deputy Director (Forecasting Services)
      - Met O 2 (Central Forecasting)
      - Met O 6 (Defence Services)
      - Met O 7 (Public Services)
    - Deputy Director (Communications and Computing)
      - Met O 5 (Telecommunications)
      - Met O 12 (Data Processing)
      - Met O 22 (Systems Development)
    - Deputy Director (Observational Services)
      - Met O 1 (Observational Requirements and Practices)
      - Met O 3 (Climatological Services)
      - Met O 8 (Agriculture and Hydrometeorology)
      - Met O 16 (Operational Instrumentation)
    - Met O 17 (International and Planning)

DIRECTORATE OF SERVICES

SPECIAL TOPIC—THE CENTRAL FORECASTING OFFICE

Introduction

The Central Forecasting Office (CFO) is located in the Meteorological Office Headquarters in Bracknell. Its prime functions are to provide guidance to other forecasting offices throughout the United Kingdom on the expected development of the weather and to ensure consistency in public service forecasting. The Central Forecasting Office has been in existence in one guise or another since 1 April 1879 when daily forecasting began. It was then at Victoria Street, Westminster, but has changed locations several times since—to South Kensington in October 1910 when it was called the Forecast and Storm Warning Division and to Kingsway in November 1919. Gradual expansion led to the division of forecasting responsibilities between different offices. At the start of the Second World War the main service was moved temporarily to Birmingham and then to Dunstable in February 1940. The CFO moved into the new Headquarters at Bracknell in September 1961 and then into a newly built wing, the Richardson Wing, in Spring 1972. It has remained there to the present time, providing a service throughout the 24 hours on every day of the year.

Main responsibilities

Since the War the main responsibilities of the CFO have altered little, although the techniques and methodology employed have changed greatly as a result of technological innovation and, particularly, by the advent of increasingly powerful computers and by satellite observing systems. The CFO's most important international role is as a Regional Meteorological Centre in the World Weather Watch system of the World Meteorological Organization. It is responsible for providing analyses and forecasts, in chart form or as coded messages, to other European National Meteorological Centres. The area covered for this purpose includes a large part of Europe, the Mediterranean, the North Atlantic and the Arctic. The CFO has the capability, however, of providing, if necessary, weather analyses and forecasts for any part of the world.

At the national level the CFO provides guidance to civil and military forecasting offices throughout the country. Charts showing the actual and expected synoptic situation up to five days ahead are transmitted to them, together with advisory texts which discuss these developments and describe the likely accompanying weather. The many outstations involved in forecasting for commerce, industry and the general public take their lead directly from the guidance issued from the CFO, adapting the forecasts for particular users and dealing in detail with the regional and local weather aspects. Thus, there is close co-ordination between the CFO and other forecasting offices serving the public such as the London Weather Centre (LWC). Conferences are held several times a day between the CFO, the LWC and the 'Weatherman' at the BBC Television Centre to discuss the weather developments to be expected.

In the special cases of civil and military aviation, which together command a large part of the forecasting effort of the Office, the situation is somewhat different. For each, there is a Principal Forecasting Office (PFO) dedicated to the provision of flight forecasts for use directly by the aircraft operators or at aviation forecasting offices at aerodromes and elsewhere throughout the country. The PFOs, located at Heathrow (civil) and High Wycombe (military), necessarily have a good deal of independence in the work that they do in their specialized fields. They nevertheless make extensive use of certain forms of the CFO output and especially in forecasting the winds and temperatures encountered by the aircraft in flight and the weather that may be significant for them.

The officer-in-charge of the operations of the CFO at any given time is known as the Senior Forecaster (see Plate I). He is responsible for appraising the weather information that streams into the Office from all parts of the world and for deciding upon the most likely future weather developments. With new and sometimes conflicting information being constantly received, the duty Senior Forecaster is faced on every day with a unique and complex problem that he must solve in a very limited time, always with incomplete data and often in a fast-changing weather situation. Fortunately, he has the help of a complex of computers, collectively known as COSMOS, which includes the world's most powerful vector processor, the CYBER 205, and which is at present unrivalled in the other meteorological services of the world.

The analysis process

The forecasters in the CFO have a considerable amount of information to digest and they must be adept in discerning what is immediately relevant. Typical numbers of reports received during 24 hours are 27 000 from surface land stations, 3500 from surface ships, 2500 from upper-air soundings stations, 3000 from aircraft, 3500 satellite temperature soundings and 1000 winds deduced from the movements observed by satellite of clouds. These come from all over the world although some areas, particularly the southern hemisphere and the oceans, are less well represented. The North Atlantic Ocean is rather better served but there can still be awkward gaps in the observational coverage causing uncertainties in what is a critical area for weather developments near the British Isles. To make sense of this vast amount of data they are plotted on charts, for various levels in the atmosphere, which enable the geographical distribution of the weather to be examined, or on special thermodynamic diagrams known as tephigrams which enable the vertical structure of the atmosphere to be studied and various properties such as its static stability to be assessed. For the most part, the plotting processes are fully automated but some charts are still plotted by hand so that the old manual plotting skills can be retained for limited use should the automatic devices fail. The scales of the weather charts vary from 1:3 million for the British Isles charts, which are plotted hourly, to 1:30 million for charts which cover each hemisphere and are produced every twelve hours.

The plotted charts are analysed by hand. The most familiar of these to the general public are the surface synoptic charts which portray the mean sea level pressure field, with its depressions, anticyclones and other features, by means of isobars, and include the warm and cold fronts, etc, separating the different air streams. However, the fields of temperature, wind and humidity over the whole of the globe are analysed by objective numerical methods for 15 separate levels of the atmosphere using the COSMOS computer system. These fields are used to specify the initial state of the atmosphere from which the numerical forecasting proceeds and, consequently, they need to be as accurate as possible. At any one time, two analysts are engaged in the CFO to monitor the assimilation of the observational data by the computer and in correcting or rejecting observations judged to be erroneous. By introducing additional simulated observations in regions with few or no data, it is possible for the analysts to intervene in the numerical analysis process to ensure that the initial state of the atmosphere is specified realistically for all areas of the world. The analysts carry out their task using several visual display units (see Plate II) which are linked to the computer and enable them to work interactively with it, calling, for example, for display of those observations which have been queried as suspect according to preset criteria and which require to be confirmed, amended or rejected. The evidence is not always clear cut but the analysts' decisions can be crucial for the success of the forecasts particularly when rapid changes are under way and severe weather threatens.

Considerable use is made of observations made by radar and by satellite which have greatly improved the meteorologist's ability to analyse cloud and precipitation patterns. As a result of work at the Meteorological Office Radar Research Laboratory at Malvern, described on Pages 102–103 of this report, a composite display of the rainfall observed over a large part of England and Wales by radar, is available to the forecasters. The displays are updated every 15 minutes and it is possible to run a sequence of them on the visual display unit so that the past progress and development of the rain areas can be monitored.

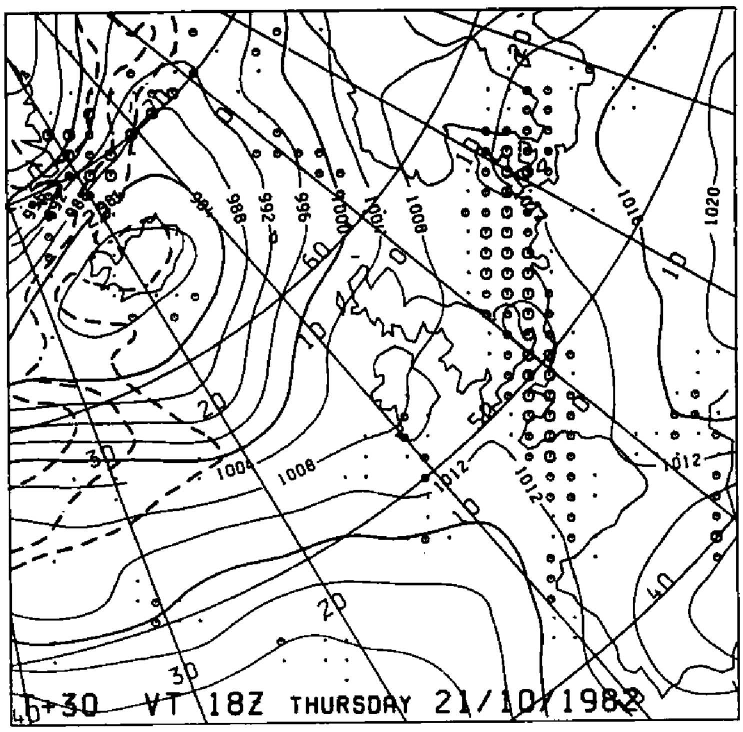
Satellite pictures generated from sensors responsive to radiation in the visual and infra-red wave lengths have been contributing to the forecasters' appreciation of the current weather situation for many years. With the advent of the fixed field of view pictures obtained from the satellite Meteosat-2 it has been possible for moving-picture sequences for the European area to be displayed. The satellite display unit in the CFO allows the pictures to be viewed with selected degrees of magnification and contrast of shade (see Plate III). Satellite imagery is also available from the polar orbiting satellites of the United States and these provide information four times daily over a wider area and in more detail. More important, especially for the vast areas of the world from which little weather data are otherwise received, the sensors on the polar orbiting satellites also provide information on the distribution of temperature in the atmosphere. The derived vertical temperature soundings have been improved to a level of accuracy that permits them to be used with telling effect in global weather analysis. Together, radar and satellite data provide the weather analyst with a much more detailed and uniform picture of the weather situation than could be obtained from the sometimes widely-scattered synoptic surface and upper-air weather observations. The latter, however, are in most respects more accurate and they measure elements that form the essential input to the numerical forecasting models and cannot as yet be observed adequately by remote sensing.

The forecasting process

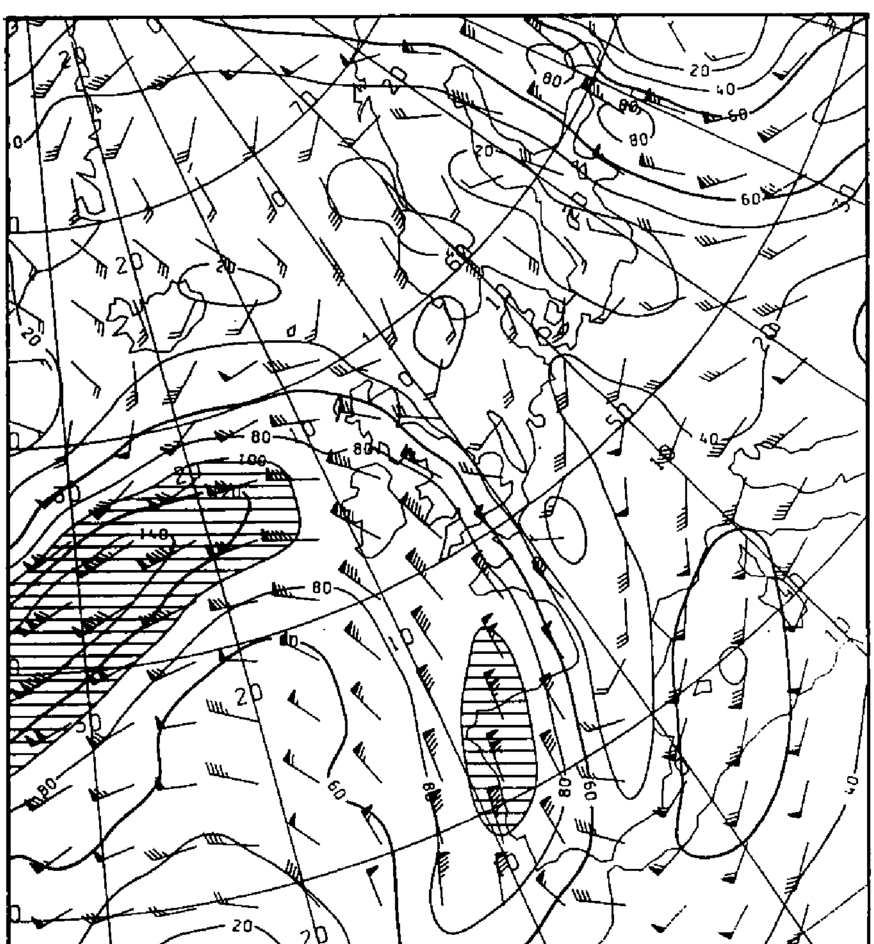
At the heart of the forecasting process lies the numerical weather prediction system. Over the last 30 years the development of more and more powerful computers has enabled increasingly complex models of the atmosphere to be formulated and used for predicting the movement and development of weather systems over longer and longer periods with increasing accuracy. Numerical weather prediction involves the solution of a set of mathematical equations which embody all the relevant dynamical and physical processes which take place in the atmosphere. These are extremely complex and, so far, the experience has been that the more sophisticated are the simulations of the atmospheric processes in the numerical models, the more accurate are the model predictions. The two very advanced models currently in use in the CFO were brought into operational service in 1982. Their formulation is described in detail on pages 75–93 of the *Annual Report* for 1980. One of them, known as the coarse-mesh model, covers the whole earth and requires repeated calculations to be made for each of over one-third of a million points spread over the globe in a regular grid of mesh around 150 km and set out in arrays over each of 15 levels in the vertical. This compares, for example, with the grid of fewer than 6000 points used for the operational model current in 1970. The model levels extend from the earth's surface up to the 25 mb pressure level, about 25 km above sea level, but their vertical separation varies so that more are concentrated in the layers of the atmosphere which are more critical from a dynamical point of view, that is to say in the atmospheric boundary layer close to the earth's surface and in the high troposphere where the fast-flowing jet streams carrying much of the atmosphere's momentum are to be found. The second model, known as the fine-mesh model, is similar in many respects to the first and has the same distribution of levels in the vertical but the grid length is smaller at each level, being set at a distance of 75 km, although there is the potential for it to be reduced to 50 km should this prove beneficial. Whereas the coarse-mesh model can be used for forecasting in any part of the world, the fine-mesh model is intended for predicting the weather in greater detail closer to home and its geographical extent is relatively limited although it nevertheless covers most of the North Atlantic Ocean and Europe. No other weather service has models working routinely with such fine resolution over an area of this size.

The range of products output from the model for the benefit of the forecasters, or for transmission directly to the end users, is very wide. Figure 1 contains a small sample relating respectively to the forecast mean sea level pressure pattern and distribution of rainfall, to the wind field at the 300 mb level, to upper winds and temperatures in the eastern Mediterranean as forecast for aircraft operations and to predictions of the height of ocean waves as derived from numerical forecasts of wind close to the sea surface. Whilst these are still early days for the new models and it is too soon to provide entirely reliable sets of verification statistics, the results so far have been very encouraging and many of the objective statistics, derived as routine each month to assess the accuracy of the numerical forecasts, show the smallest errors yet achieved. There is a particularly significant improvement in performance for periods beyond 24 hours, the new model showing an impressive ability to deal with rapidly deepening depressions and to develop pressure systems after one or two days or more which did not exist at the time of the initial analysis. Figure 2 shows with what skill the model dealt with the development of a record-breaking depression during 17–21 December 1982.

Notwithstanding the great help received from the numerical models, there is still much for the Senior Forecaster, supported by his specialist team, to do. Having digested the essential features of the current weather situation over a substantial part of the globe, he must then examine the output of the numerical weather prediction systems in use at Bracknell and those received from two or three other centres, principally in Washington and Frankfurt. For periods beyond one or two days, he also has available the products of the European Centre for Medium Range Weather Forecasts. The Senior Forecaster then has

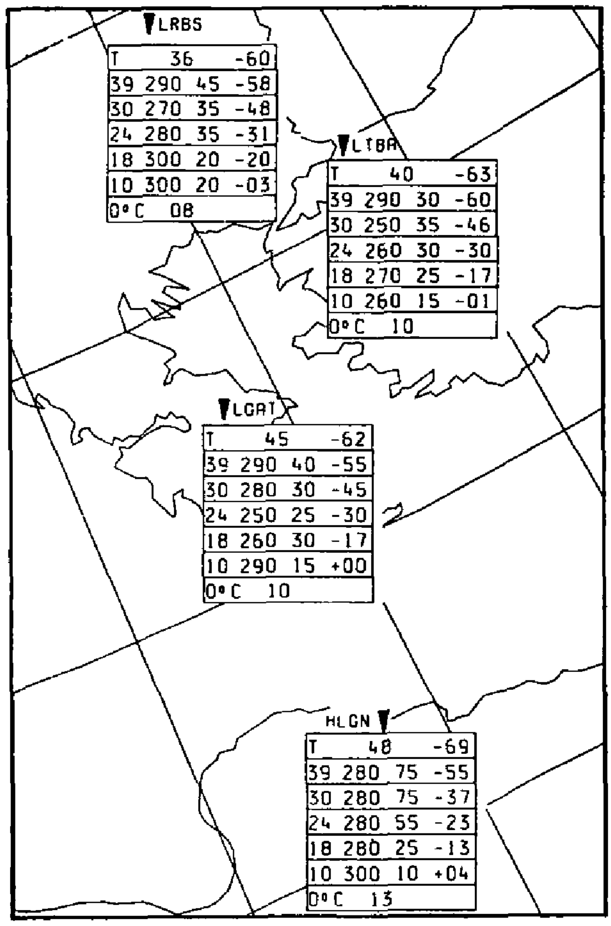


(a) Surface pressure and rainfall forecast

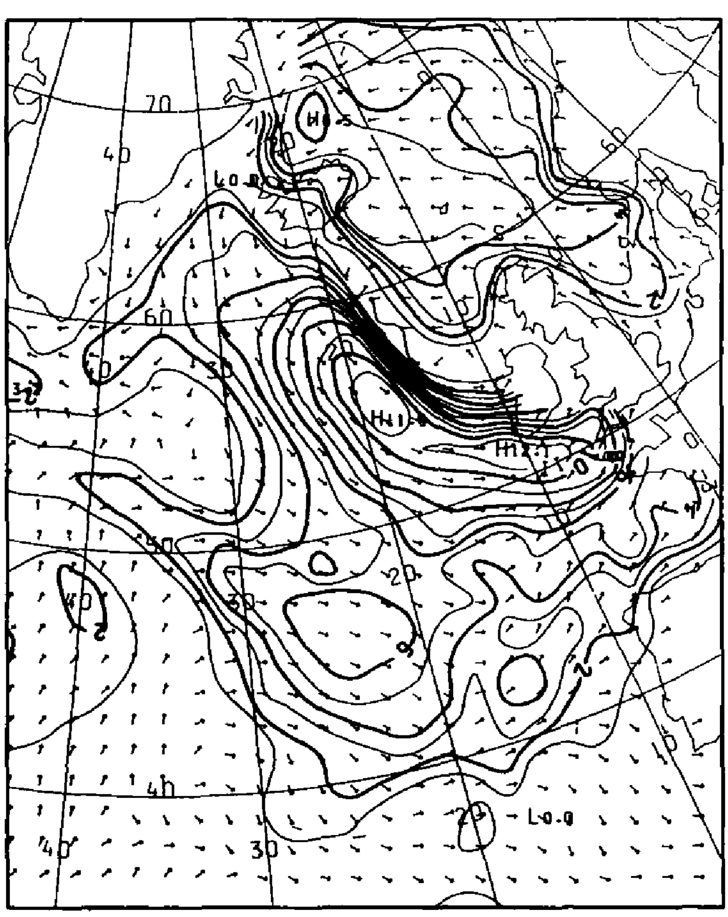


(b) 300 mb upper-wind forecast (shaded areas are winds in excess of 100 knots)

Figure 1—Sample products from the new numerical models

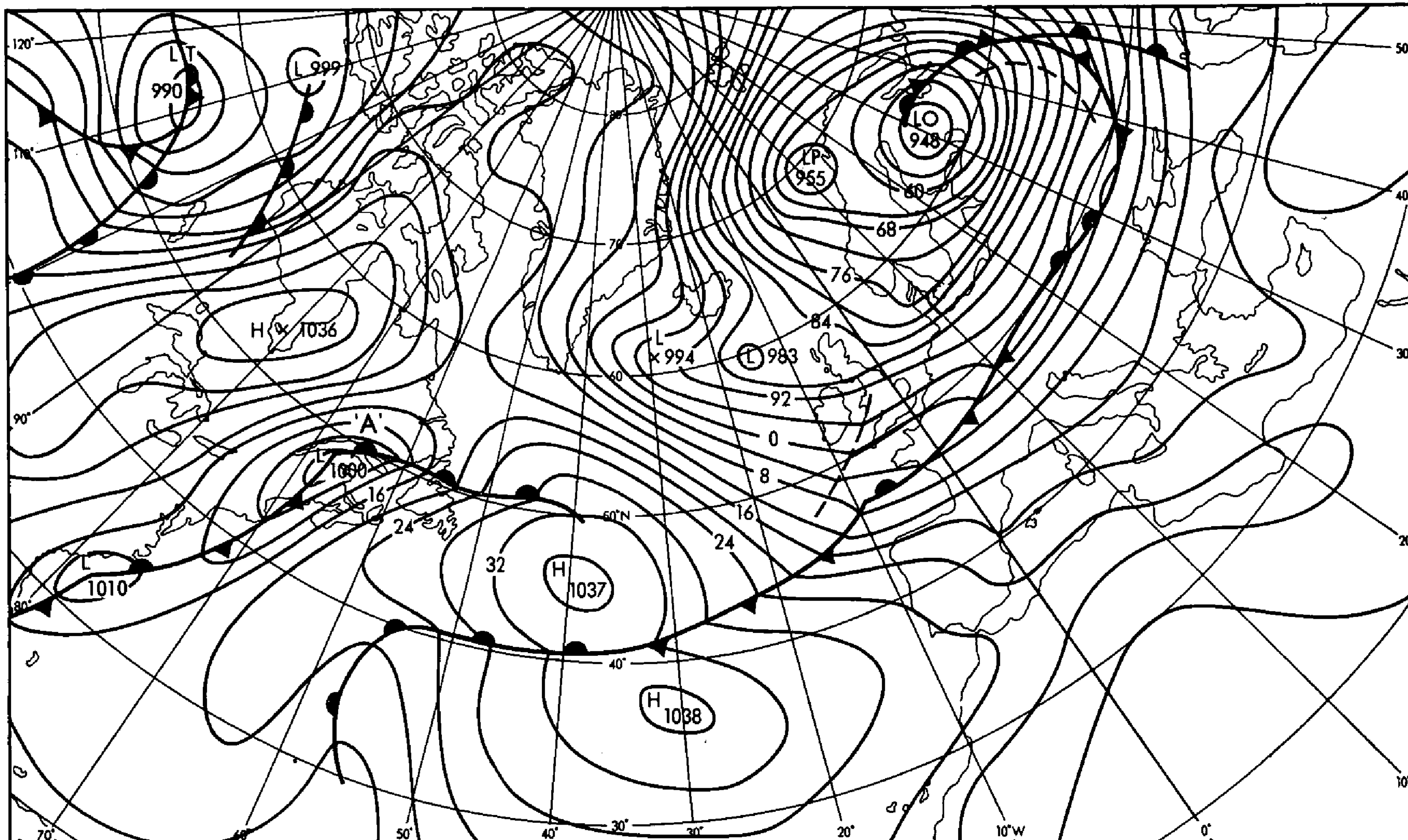


(c) Spot wind and temperature forecasts for international airports around the eastern Mediterranean



(d) Wave forecast (the contours are forecast wave heights—up to 12 metres west of the British Isles)

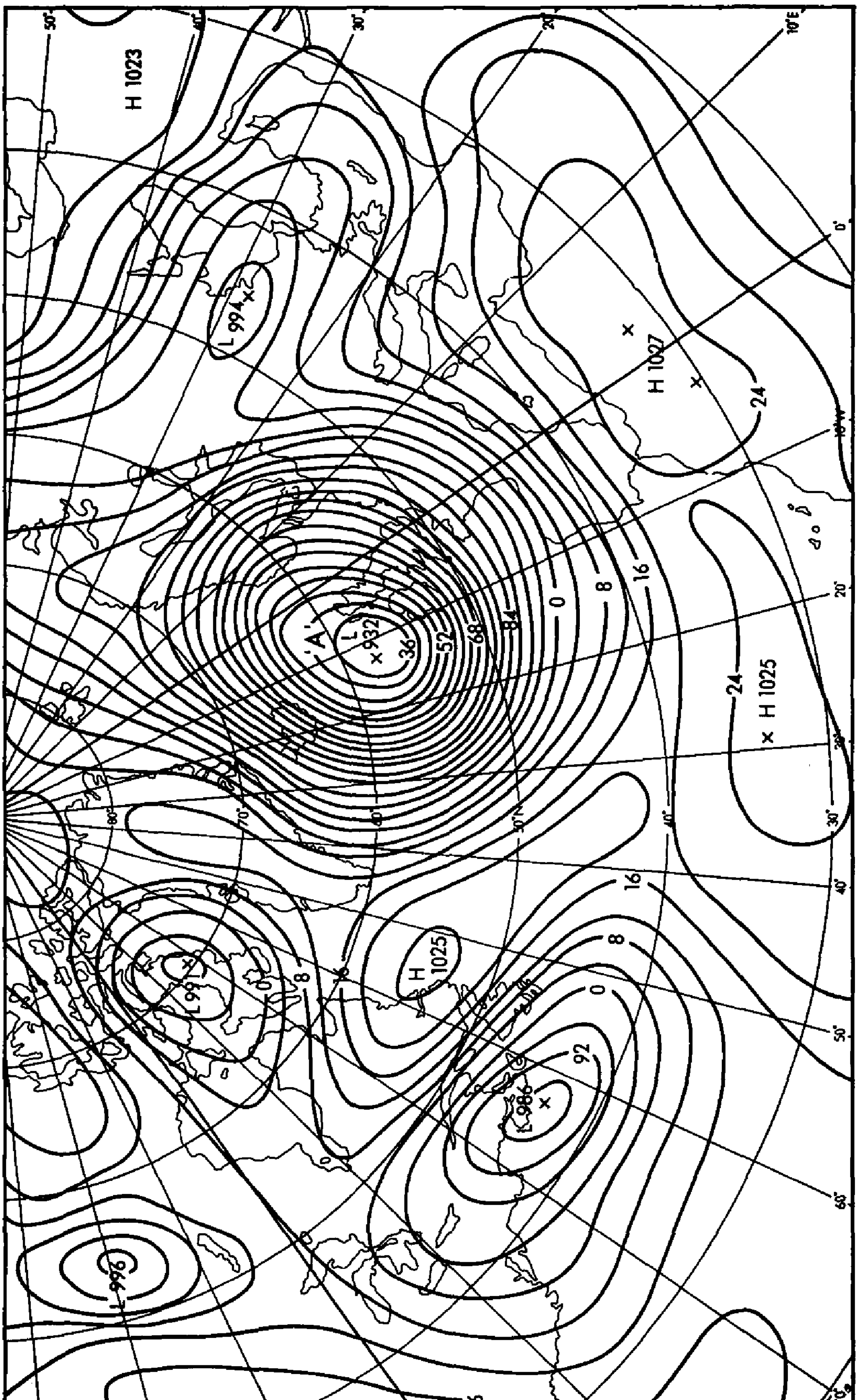
Figure 1—*continued*



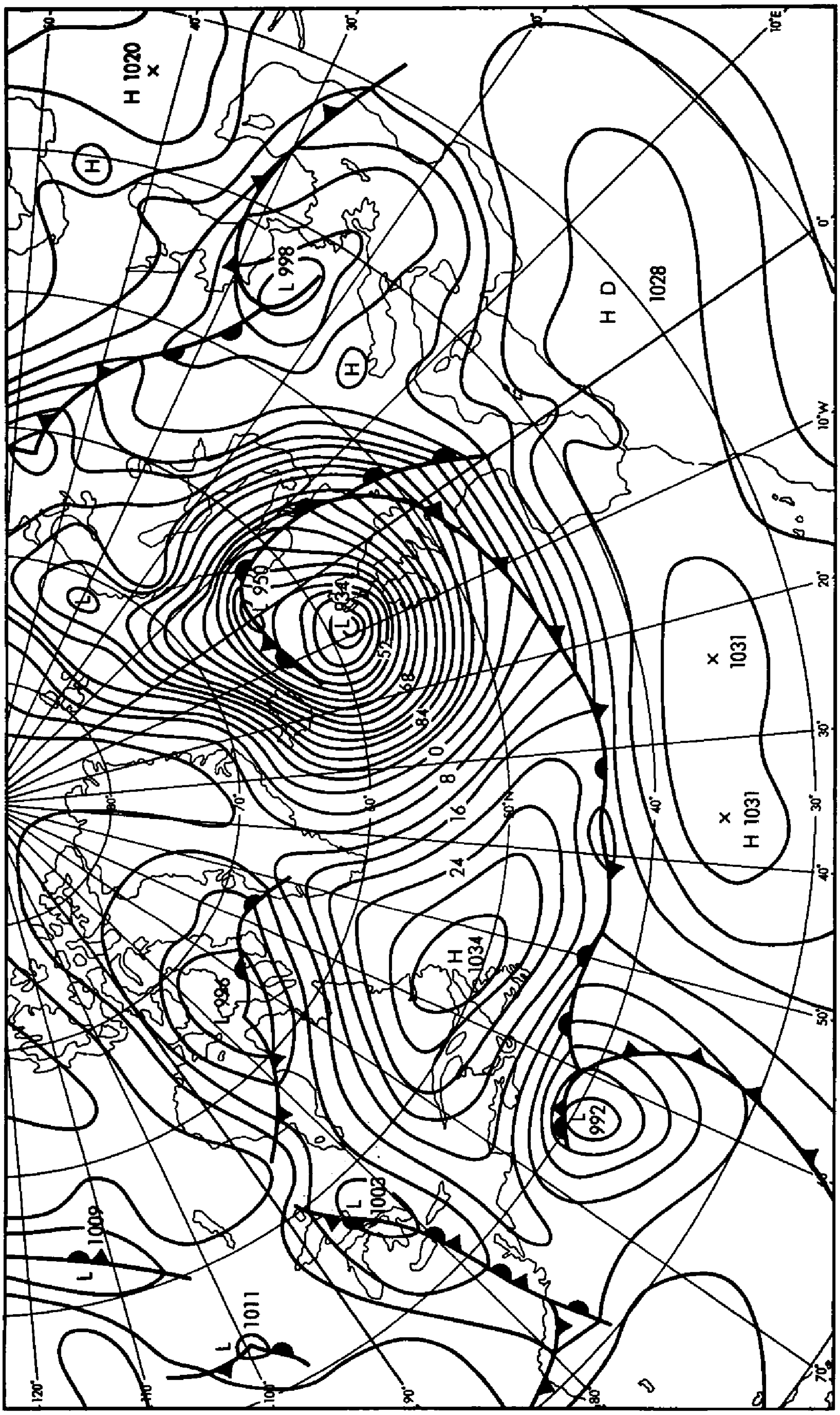
(a) CFO analysis for 0000 GMT on 17 December 1982

Figure 2—A 72-hour numerical forecast for 20 December 1982

The depression over eastern Canada on 17 December was correctly predicted to move quickly eastwards to the west of Scotland and deepen dramatically.



(b) 72-hour numerical forecast for 0000 GMT on 20 December 1982

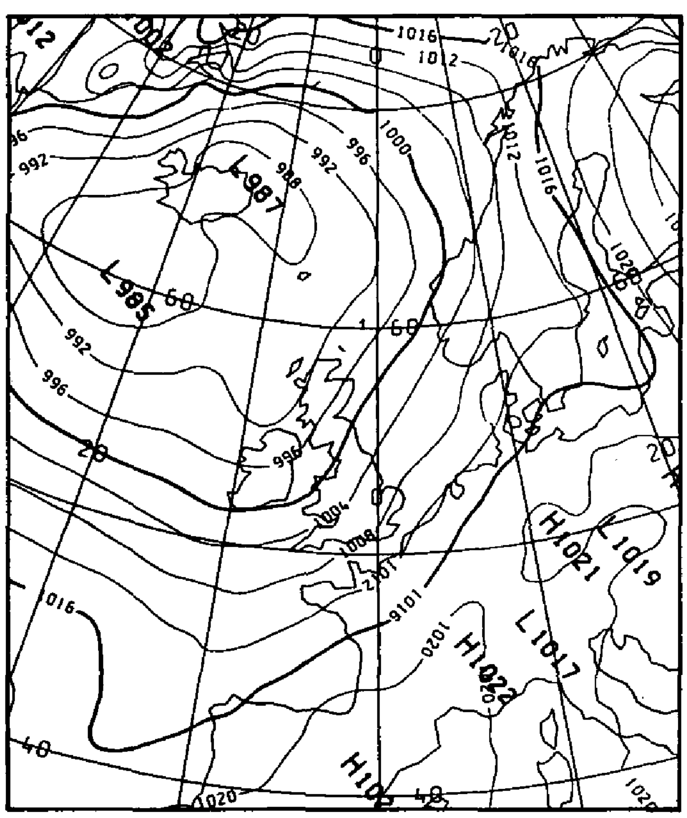


(c) CFO analysis for 0000 GMT on 20 December 1982 to form an opinion on the extent to which the model outputs can be used as a basis for the various forms of guidance that he requires to originate. He may be faced in this situation with somewhat contrary indications from the model outputs of the different international centres or apparent conflicts between their predictions and the currently observed trends in the development of weather systems on their various scales. He therefore has to make judgements that call for a sound knowledge of the physics and dynamics of the atmosphere, of the physics and dynamics incorporated into the numerical weather prediction models, and of the characteristic behaviour patterns of both the models and the real atmosphere. This somewhat subjective process involves consideration of many factors. The Senior Forecaster may have more recent data than were available at the time of the numerical computations and be able to judge whether the early model output is on the right lines, later satellite pictures may show that the initial analysis from which the model computations began was deficient in some respects and this must be taken into account, and he may occasionally have to call on older, more traditional, forecasting ideas and techniques now mainly superseded in the computer age. Drastic departures from the model indications are uncommon nowadays, at least in 24-hour forecasting, although this was not the case even as little as ten years ago. Figure 3 shows, however, what the Senior Forecaster may add. In this case the model failed to develop an intense small-scale depression and the Senior Forecaster's amendment led to a successful forecast of a severe gale.

Forecast charts for 24 hours ahead covering Europe and the North Atlantic are prepared every six hours. These are distributed internationally and to Meteorological Office outstations. Plain language texts, the Synoptic Reviews, are prepared. These discuss the expected weather developments and the uncertainties of the situation with underlying reasoning. Particular reference is made to gales, thunder, fog, snow, frost, icy roads and thaw, so that, if severe weather is expected, special action can be taken to warn the public and relevant authorities. While the final decision in each case is the responsibility of the Senior Forecaster, it is reached as a result of a team effort. The weather over the British Isles is constantly monitored as it develops in order that the probable development or time of onset of any of the notable hazards may be estimated. There is much for the forecasters to do in interpreting the numerical model output and research work is under way in several Branches of the Office to enable the most effective use to be made of the various model products in formulating the weather forecast as presented to the public or to specialist users. Another member of the team, the Medium Range Forecaster, looks after the increasing demand for forecasts in the range 2 to 5 days ahead and his guidance is produced in the form of a set of surface synoptic charts amplified by a text which deals with the uncertainties of the situation and indicates with what confidence the various developments are expected. The period that he deals with, up to 5 days, is longer than the lifetime of the average Atlantic depression. Nevertheless, with the help of the new models, it is often possible successfully to predict changes of the general weather type even when they occur towards the end of the 5-day period.

Specialized forecasting applications

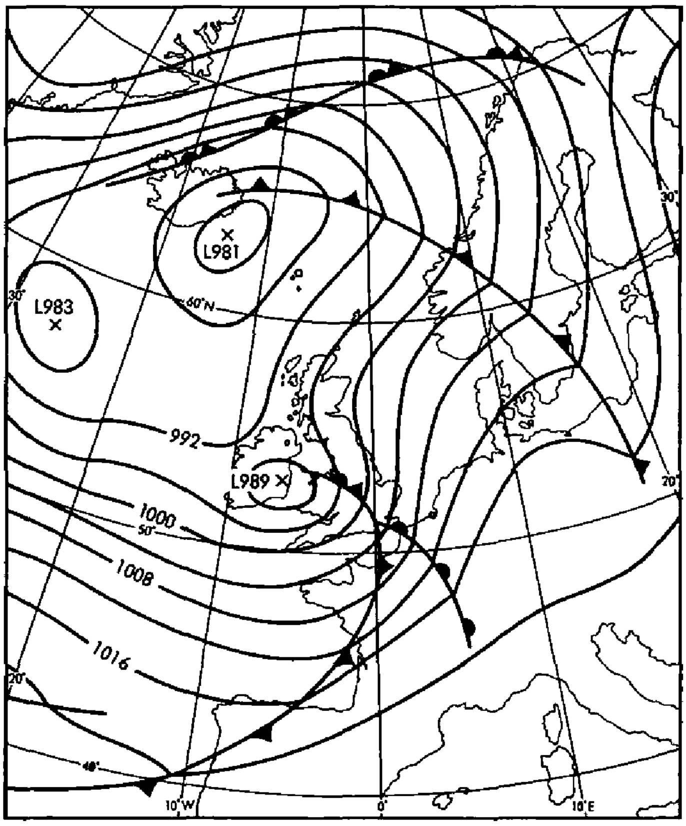
The roots of the Meteorological Office were to be found in the Department of the Board of Trade set up in the mid-nineteenth century, with Admiral FitzRoy at its head, to serve the interests of shipping in peril from storms at sea. There remains to this day a close maritime connection. The Senior Forecaster's deputy is very largely occupied with shipping matters. He (or she) originates the shipping bulletins broadcast four times daily by BBC Radio 4 and by coastal radio stations for sea areas close to the British Isles. Also of prime importance is the Gale Warning Service which provides for the continuous updating of warnings issued for the sea areas of the shipping bulletin for gales expected up to 24 hours ahead. A twice-daily bulletin is issued through Portishead Radio for areas of the North Atlantic further afield and this may include storm warnings which can be updated at predetermined times. The deputy, or shipping, forecaster provides the meteorological support for the Meteorological Office Ship Routeing Service which is manned by experienced mariners of the Marine Division and is located within the CFO. Under this service, ships which have sensitive cargoes, or which are simply looking for a fast or economical passage, can be so routed across the world's oceans as to avoid the worst of the storms. Products of the CFO are broadcast by radio facsimile for the benefit of other countries and of ships at sea which can make use of them.



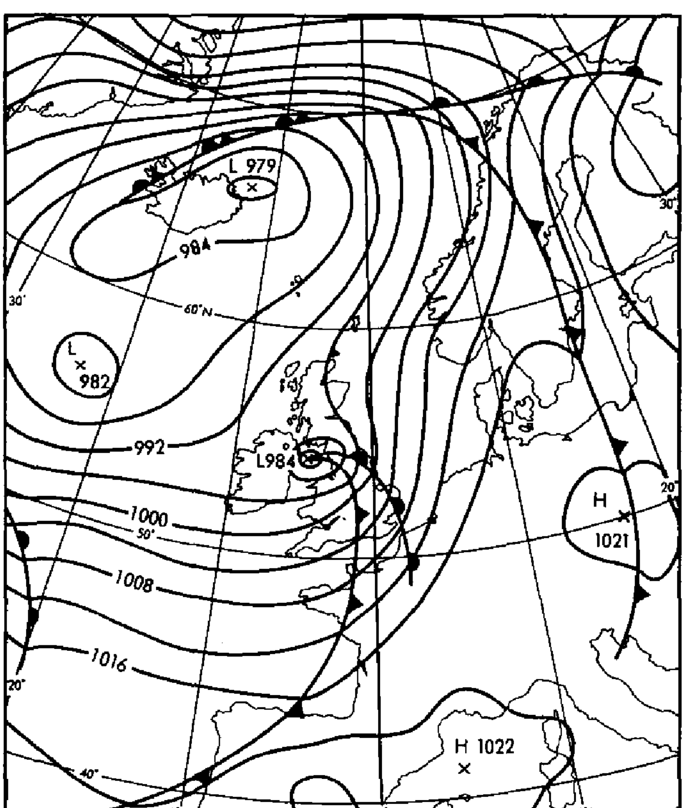
(a) 24-hour numerical forecast for 1200 GMT on 27 September 1982

Figure 3—An example of the Senior Forecaster's modification of a 24-hour numerical forecast

A shallow wave depression to the south-west of the British Isles moved quickly north-eastwards, but was insufficiently deepened by the numerical model. The depression became a vigorous one as it moved across the Irish Sea and winds exceeded severe gale force. A gust of 68 knots was reported in Anglesey and considerable damage was done to property in parts of North Wales.



(b) Senior Forecaster's 24-hour forecast for 1200 GMT on 27 September 1982



(c) Analysis for 1200 GMT on 27 September 1982

Figure 3—*continued*

They include charts containing forecasts of the height and direction of the sea waves and swell for periods up to two days ahead. These are obtained by the running of a numerical wave prediction model in conjunction with those used for numerical weather prediction, wave generation being largely influenced by the surface wind. Finer-scale surface wind and wave forecasts are also supplied to the London Weather Centre for use in their specialized services to the offshore industry. Another marine connection arises through the location within the Headquarters at Bracknell of the Storm Tide Warning Service of the Ministry of Agriculture, Fisheries and Food. The meteorologists contribute to this by providing forecasting guidance when atmospheric and tidal conditions combine to raise the risk of flooding to serious levels but numerical weather prediction models again play a part in providing input to a special tidal surge prediction model.

The Meteorological Office was placed under the Air Ministry soon after the end of the First World War in recognition of the importance of weather reporting and forecasting to aviation. The CFO played a key role in the conduct of military operations in the Second World War and while, as previously explained, the forecasting for military aviation is now led primarily from the PFO at High Wycombe, this work relies heavily on the output from the numerical models run by the CFO.

The model output and other CFO products are also sent to the Fleet Weather and Oceanographic Centre of the Royal Navy at Northwood. The ability of the CFO to provide backing for a weather forecasting service outside its normal areas of responsibility was well tested during the operations in the South Atlantic that took place following the invasion of the Falkland Islands, as is described in the section of this report which deals with the work during 1982 of the Central Forecasting Branch (pages 15–17).

In close co-operation with the PFO at London (Heathrow) airport the CFO also provides services for civil aviation both nationally and internationally to meet the requirements of the Civil Aviation Authority and of the International Civil Aviation Organization (ICAO). The PFO is designated as an Area Forecast Centre under the current ICAO Area Forecasting System. It has the responsibility for providing flight planning information and the flight weather documentation required for all flights west-bound from any part of Europe to any part of North America. The numerical model output again figures largely in this work. In practice, flight planning data are sent out from the CFO in the form of numerical values of upper winds and temperatures at agreed levels and at a standard geographical grid of points. Charts of predicted upper winds and temperatures are also prepared in the CFO and these are distributed to all parts of Europe for use by the departing aircraft. A civil aviation forecaster prepares, in addition, charts for distribution which give relevant information about the tropopause and about the jet streams which may be encountered in flight. The PFO at Heathrow produces a complementary set of charts giving details of the weather to be expected *en route* including information on hazards, such as severe icing and turbulence, which can also be deduced to some extent from the numerical weather predictions. The operators of Concorde, both Air France and British Airways, are furnished with forecasts specially prepared for the levels of the lower stratosphere at which the trans-atlantic supersonic flights take place. Accurate temperature forecasts are particularly important to Concorde since they affect the payload factors. It is encouraging therefore, that the new 15-level model is providing more accurate stratospheric temperature predictions than did its predecessor. Another, and very important, task performed in the CFO for aviation is the forecasting of the minimum pressure values used for altimeter setting purposes for certain types of flying within United Kingdom airspace. These are used to maintain safe vertical separation of aircraft and for ground clearance purposes. While the account of the work for civil aviation just given is correct at the close of 1982, as a result of planning which has been taking place in ICAO during the past five years, the CFO will soon have a substantially enhanced role to play in meeting the needs of international civil aviation. It has been designated as a World Area Forecasting Centre under a new plan which will mean that, in conjunction with one other such centre in Washington, it will provide forecasts of upper wind and temperature for flight planning and flight deck purposes for airline operations throughout the world. The CFO has been awarded this role in recognition of its currently pre-eminent position in having a global weather prediction system of unique quality and power. The Meteorological Office seems likely, in addition, to retain its European regional role in providing documentation for westbound transatlantic flights.

Little of the CFO output goes directly to the users in commerce and industry or to the general public. These interests are served, as previously explained, for the most part through the Weather Centres and other public service offices. However, certain Press forecasts and some radio scripts for broadcasts by the announcers or news-readers are written by the CFO forecasters. In addition, the Senior Forecaster takes a very close interest in the national weather presentations on radio and television, to ensure that they are relaying as nearly as possible his conclusions on the general weather developments. Of particular importance in this connection is the weekly farming forecast presented on BBC 1 at lunch time on Sundays by the Weatherman. This looks ahead for 7 days and is regarded by farmers and by many members of the public as the most useful weather forecast of the week. The performance of the new 15-level model is such that guidance of this kind will be even more reliable in future and it is to be hoped that this will be recognized by those responsible for the allocation of time for the weather forecasts in the television channels. The public and the economy will be the losers if this valuable extra weather information continues to be squeezed out of the weather presentations by their sharp curtailment as often happens, to periods of less even than a minute.

A role of the CFO that fortunately is rarely played, although sometimes exercised, is as a centre from which the best possible meteorological advice can be obtained in case of any national emergency for which the weather may be crucial, if not the cause. The kind of emergency for which provisions are made range from offshore pollution to chemical or nuclear accident. For the latter cases, computer programs are available that would enable the future trajectories to be calculated of any noxious material emitted. Standing arrangements also exist to alert the authorities to situations as they develop, in which the weather itself might play the destructive part. Special messages are passed to the military authorities to alert them to the imminence of extreme weather whenever the possibility is foreseen that the civil population may need their help. This arrangement is partly responsible for the speed with which the Armed Forces have reacted to the civil need in cases of blizzard and the like in recent years. In less dramatic circumstances there are, of course, the arrangements under which the public are warned of the imminence of severe weather by broadcast on national or local radio of special announcements or 'flash messages', as they are known. These, too, are monitored and co-ordinated from the CFO.

OTHER WORK OF THE DIRECTORATE OF SERVICES

FORECASTING SERVICES

Central forecasting

The Central Forecasting Branch consists of two sections: a Central Forecasting Office (CFO) which provides regular guidance to outstations up to five days ahead and a development section which is mainly responsible for maintaining and improving the operational numerical forecast suite. The major change during the year occurred in September when the 10-level numerical forecast system, which had been operational for the previous ten years, was replaced by a new series of computer programs embodying a global 15-level model. A description of the new system and a full account of the work of the CFO may be found in the special topic from the Directorate of Services—'The Central Forecasting Office' in pages 1–15 of this report.

The CFO is manned 24 hours a day and has important international and national commitments. Internationally, the CFO is a Regional Meteorological Centre within the World Weather Watch of the World Meteorological Organization with responsibility for an area covering much of Europe, the North Atlantic and the Arctic. Analyses and forecasts are provided in different forms to a number of European National Meteorological Centres. Nationally, the CFO is the principal analysis and forecast centre of the Meteorological Office and provides daily guidance to outstations in chart and text form covering a period up to five days ahead. Special attention is given to the provision of warnings for the public in hazardous weather conditions.

For details of the variety of guidance originated in the CFO as routine the reader is referred to the special topic, mentioned above. In 1982, however, the Central Forecasting Branch was requested at short notice to provide support for Operation Corporate, the code-word adopted for the military measures taken in countering the invasion of the Falkland Islands and their dependencies in the South Atlantic. Before the invasion, the then experimental numerical forecasting model was available in a form that would not provide forecasts in the southern hemisphere south of 30°S. The data assimilation was, nevertheless, being performed globally and there was therefore a basis for the preparation of global forecasts and, in particular, forecasts for the South Atlantic. By working continuously throughout the weekend following the invasion, staff of the Branch modified the system so that global forecasts for up to three days ahead could be produced twice-daily. Few adjustments to this system were needed subsequently for the duration of the crisis and it proved to be so robust that little use had to be made of back-up products from other sources.

A separate forecasting cell was set up in the CFO to provide forecast data and forecasting guidance to the military staff concerned and to the meteorologists in the field in Ascension Island and the Falklands. Qualified staff were drafted in from other Branches to provide the necessary manpower. Amongst the recipients of the South Atlantic forecasts were the forecasters at the Fleet Weather and Oceanographic Centre at Northwood with whom there was very close liaison. Since very few conventional weather observations were available from the South Atlantic, although some came from the Royal Navy and Royal Air Force units engaged there, information obtained by weather satellite played a very important part. Plate IV contains a satellite cloud picture for 25 July with the Falkland Islands lying in less cloudy air behind a cold front. For the numerical models, the satellite temperature sounding data were also very important and work carried out in the Satellite Meteorology Branch of the Office ensured that particularly detailed information was available. Thus the South Atlantic forecasters had a variety of material to help them to ensure that the initial analyses used for the computer forecasts were as accurate as possible.

The weather forecasts required for Operation Corporate were, of course, much concerned with surface and low-level weather conditions in the areas of immediate operational interest. Examples of a numerical 24-hour forecast surface chart for the South Atlantic and of the verifying analysis for the same time are given in Figure 4. Forecasts were also needed of the winds and temperatures to be expected at various flight levels for the missions and transport operations undertaken from Ascension Island. These were sometimes crucial in view of the very long distances flown and the complicated in-flight refuelling operations that were carried out. Computer routines were developed to cater for the large amounts of forecast upper wind and temperature detail required and obviate the need for many supporting charts. With the cessation of hostilities the need for close support diminished and the special South Atlantic cell was disbanded. Output from the CFO for the South Atlantic continued to be provided to the end of the year, however, as routine, twice-daily.

During the year as a whole the development section of the Branch has been engaged primarily in the operational implementation of the new 15-level numerical weather prediction system. This work has been done in close liaison with the members of the Forecasting Research Branch responsible for the design of the data assimilation scheme and the numerical forecasting model. Field trials of the new programs for both fine-mesh and coarse-mesh versions of the numerical model have led to progressive improvements in performance. Some of these were planned; others resulted from the correction of deficiencies detected by detailed evaluation. A major programming effort was required to assemble and prepare the data prior to their use by the objective analysis scheme and also, following the computations of the analyses and forecasting phases, to output the results in various formats for use by the forecasting staff or for direct use by customers. These may be in chart form or as coded alphanumeric information. The chart products broadly parallel those available from the previous operational suite of programs with improvements resulting from the use of a new mapping program written by the Systems Development Branch.

Forecast grid-point data were made available to British Airways for flight planning purposes from the new model in June, some three months ahead of the model's introduction for routine forecasting in general. This enabled British Airways progressively to apply it for routes extending throughout the northern hemisphere and in the southern hemisphere to 30°S. With a fully global version

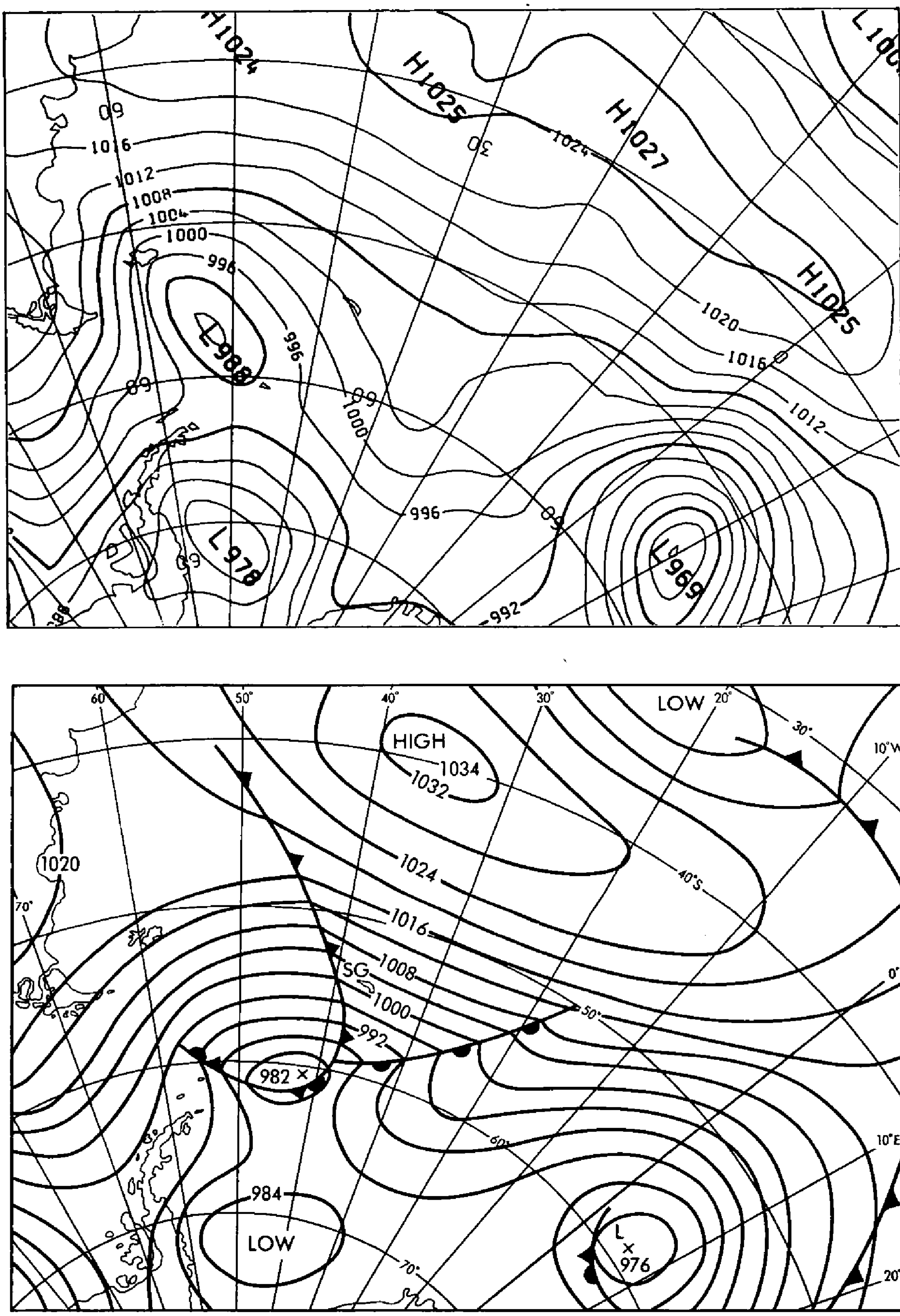


Figure 4—A 24-hour numerical forecast for 1200 GMT on 25 April 1982 for the South Atlantic (upper) and the verifying analysis for the same time (lower)
Successive forecasts indicated a brief spell of less stormy weather as a ridge between two depressions moved quickly eastwards across South Georgia, which was recaptured that day.

of the operational model on operational trial in December it was expected that global data would be made available to British Airways early in the New Year.

The performance of the new model was routinely assessed both subjectively and objectively to enable problems and advantages of the new numerical prediction scheme to be detected. Objective verification programs were run regularly to monitor the performance of the numerical products. A diagnostic programming package was prepared to calculate mean features of the model patterns of temperatures and winds to assist in the appraisal of the new system. The Branch is also responsible for collating forecast verification statistics relating to other forms of output including hand-drawn charts and worded scripts.

The numerical models to predict sea waves and swell were re-programmed during the year to run on the CYBER 205 computer. Besides utilizing the improved surface wind produced by the new 15-level atmospheric model, the wave models are more complex than those they replaced and cover a larger geographical area. Of particular importance is a fine-mesh model which is used at the London Weather Centre for forecasts for the offshore oil industry.

A six-month long trial of a statistical forecasting technique known as Model Output Statistics (MOS) took place in CFO in the first half of the year. The basis of MOS rests on establishing a statistically significant relationship between observed weather variables such air temperature or visibility, and forecast parameters given by a numerical weather prediction model. During the trials, the statistical temperature forecasts at 16 locations for up to four days ahead gave encouraging results, especially for the larger forecast periods, being at least as good as subjective forecasts.

A separate unit within the development section of the Branch supports the Outstation Automated Systems (OASYS) by maintaining and developing software for those installed at Heathrow Airport and Headquarters Strike Command, Royal Air Force. Experiments were initiated on the presentation of numerical forecast data for the television services and for outstation use.

Services for industry, commerce and the general public

At the beginning of 1982 there was a heavy demand from the general public for weather services as a result of the severe wintry weather which affected most parts of the country during December 1981 and early January 1982. The casual enquiries to Weather Centres increased by some 30 per cent over corresponding periods of the previous winter, and at times jammed their switchboards. Press, radio and television requests for information and comment were also significantly higher. The staff worked under considerable pressure throughout the period to ensure that all contracted forecasting services were maintained. When access to the Weather Centres was not possible, information was sought from alternative sources such as Weatherline, previously known as the Automatic Telephone Weather Service, and Prestel, both of which were in unusually high demand. Probably there were similar increases in the number of people who used CEEFAX and ORACLE. These services are described more fully below.

Forecasting services for the general public, commerce and industry are provided from a network of public forecasting offices distributed throughout the United Kingdom. At some civil and military aerodromes a limited amount of public service work is undertaken by the forecasting offices to the extent that their primary tasks permit. Eight offices, known as Weather Centres, are established primary to provide public services. One of these, in Cardiff, functions as a Main Meteorological Office (MMO) with certain additional responsibilities for civil and military aviation. During 1982 a study group has examined the possibility of rationalizing services to civil aviation and the general public in south-west Scotland and its report was under study with the Civil Aviation Authority at the end of the year.

Planning was also initiated to meet in an alternative way the public service commitments of the Meteorological Offices at RAF Honington and RAF Bawtry.

General forecasts are prepared for dissemination by the media (television, radio and newspapers) at no direct cost to the general public. More detailed forecasts which are updated several times daily are available from the British Telecom Weatherline service and on Videotext systems at a relatively low cost to the public. All Weather Centres and certain other public service offices are listed in telephone directories to allow access by the public to a forecaster. This facility has been under strain at times during the year as a result of increases in demand for specialized services and temporary shortages in staff due, amongst other things, to events in the South Atlantic. The service given in answering casual telephone enquiries at the Glasgow and Nottingham Weather Centres and at RAF Pitreavie, and Edinburgh had to be suspended for short periods. Every effort was made to minimize the inconvenience and enquirers were directed to alternative sources of information by recorded messages. There was no break, however, in the dedicated forecast services provided on a regular contractual or consultancy basis for a wide range of weather-sensitive activities including transport, power, construction, farming and leisure. These specialized forecasts are most often issued in a format designed to meet the specific requirements of the customer but there has been an increase in the number of clients who take the more flexible consultancy services now on offer. Instead of receiving weather advice in a set format at fixed times, the client taking a consultancy service can seek the advice of a forecaster using an ex-directory telephone number, as and when required. This is particularly useful to those such as farmers for whom different elements of the weather are important according to the season, or to the state of a crop, or to the job in hand, and who can plan their work for a few hours or a few days ahead in keeping with the weather expected. Many other enterprises are finding it worth while to have such advice on call.

In general the amount and quality of the weather information provided through television increased significantly during 1982. There were no changes worthy of note in the presentations given by the weathermen but live presentations began on BBC Wales in November following a similar development with Harlech (ITV). In both cases forecasters from Cardiff Weather Centre were involved. Scottish Television (ITV) also introduced a live presentation of the weather forecast during August, forecasters from Glasgow Weather Centre taking part. BBC Ulster experimented with a live forecast service during August and September as part of a special summer features program. BBC West decided that they could no longer take a daily live presentation from the Bristol Weather Centre and this service was reduced to a Friday evening appearance from the end of July. In the whole United Kingdom there remains only northern

England which is not served by a personal presentation of weather on television. In most other areas weather presentations are made either by members of the Meteorological Office from the nearest Weather Centre or delivered by privately employed presenters who are supplied with information by the nearest Weather Centre.

A good deal of effort has been put into the development of a more dynamical form of weather presentation for television. A MOD film unit, Services Sound and Vision, collaborated in the production of a short film which included animated sequences of satellite pictures and of forecast products such as temperature, humidity and wind. The film was shown to several national and regional television companies including the BBC, Channel 4, TV-am and Satellite TV. Channel 4 became the first company to experiment with a new style of presentation when programs began in early November. This consisted of a filmed sequence of forecast charts with a commentary prepared by a forecaster at London Weather Centre and delivered by a member of the Channel 4 staff.

The steady expansion of live radio broadcasts on local BBC and IBA stations has continued. By the end of 1982 no fewer than 40 radio stations were carrying broadcasts made live by members of the Office, an increase of 10 over the twelve month period. Plans for three more new services, with starting dates in early 1983, were agreed with the companies concerned. Most other local radio stations use scripts prepared by nearby forecasting offices and services to the media now take, in total, over 10 per cent of the public service forecasting effort.

The upsurge in media interest has called for a continual process of training, auditioning and selection of staff for the specialized broadcasting duties. To prepare forecasters for much wider and more versatile roles a public service element was added to the Initial Forecasting Course during the year. A radio and television studio has been established at the Meteorological Office College so that forecasting staff can have instruction in radio and television presentation techniques as an integral part of their basic training program.

In addition to the routine broadcasts on radio and television already described, Office staff were involved in many other programs during 1982. The severe weather in January prompted a large number of requests for interviews in news programs. Two of the BBC weathermen featured in series of programs in the early summer. Jack Scott, the senior BBC TV weatherman, appeared regularly during the 'Holiday' series on BBC 1 in July and Jim Bacon presented a regular weather feature in the 'Travel' program shown during July and August on BBC 2. The BBC 2 program was a new venture in that the weatherman appeared as a co-presenter. A BBC audience survey revealed that the weather was the most popular part of the program series.

The amount of weather information provided to Prestel and Teletext grew steadily in 1982. The number of Prestel users slowly increased although the numbers are still well below the original Post Office predictions. The majority of users are in the commercial rather than in the domestic field and the selection of material offered has reflected the needs of the known groups of users. A popular development has been the large increase in the number of reports of current weather which are now displayed for cities throughout the world. Regional, national and extended period forecasts, present weather reports and weather statistics are kept constantly updated by a team of operators at Bracknell, using information provided by weather offices in this country and around the globe. The Meteorological Office has acquired a reputation within the Prestel community as a model information provider and it has figured amongst the top 30 most accessed sources in every month of the year. The Office has been closely involved in a growing trend towards the provision of information for specialist users of viewdata, sometimes within closed Prestel user groups or within private viewdata systems. It has co-operated, for example, in a study into the feasibility of marine videotext for use by HM coastguard service. The Office has also been co-operating in a project, supported by the Department of Industry, to provide domestically orientated information of local interest in the West Midlands. Such developments are expected to lead to an increase in the revenue for the Office. General weather forecasts are also provided to CEEFAX and ORACLE, the BBC and ITV Teletext systems, on a national basis and the provision of regional forecasts for ORACLE began during the year.

A Weatherline service was introduced in the Grampian area during the year but owing to technical difficulties within British Telecom other planned extensions of the Weatherline coverage remain to be made. The number of calls to Weatherline has increased very significantly in recent years but there is considerable scope for expansion yet and with help in advertising from British Telecom more people are being made aware of the existence of the service. In 1982 the number of calls to Weatherline totalled 25 510 988, a figure which compares with 30 310 956 in 1982, a year with spells of particularly inclement weather, and 25 967 894 in 1980.

The numbers of enquiries to the Weather Centres have remained at high levels but were less than they might otherwise have been as a result of the unavoidable restriction of casual telephone access to some Weather Centres at times during the year.

The increased use of the consultancy services by commercial interests has already been mentioned but many other services tailored to the use of a particular industry are regularly provided. One of the most important of them for the national economy is that provided to the off-shore industry. This is described more fully in the section on 'Services for marine activities' (page 22). The gas and electricity industries are also major users of specialist meteorological information and a dialogue is maintained with the corporations concerned on the scope for improvement in satisfying their operational requirements provided by technical innovations in weather forecasting. The power industries can adjust their outputs to the expected demand using weather forecast information and industrial energy managers can use the information to minimize power consumption for the heating of offices and factories. Although there has been a steady increase in the number of such specialist weather forecast applications, there remains a large untapped potential for cost-effective use of weather information, with a consequential saving of the energy resources of the country.

The revenue from forecast services to industry and commerce rose by over 17 per cent in the financial year 1981/82 compared with 1980/81 notwithstanding the effects of the industrial recession. To test the awareness of industry and commerce of the availability of its specialized services, the Meteorological Office commissioned National Opinion Poll Market Research Ltd (NOP) to conduct a survey within certain areas of industry and commerce. The groups sampled throughout Great Britain included energy managers, builders, farmers, growers and road hauliers. Amongst other things the survey demonstrated that there is a large market for weather information but that relatively few know what specialized services are available. Very few respondents had any idea of how cost effective their use of the weather forecasting services could be. As a result of the survey a more vigorous promotion of the specialized services is planned for 1983, but the resources available for this will necessarily be limited.

During 1982, the Meteorological Office participated in a number of exhibitions, the design and construction of the stands being sponsored for the most part by the Central Office of Information (COI) and the MOD Directorate of Promotions and Facilities (MOD(DPF)). The major exhibitions included Oceanology 82 at Brighton and the Royal Show at Stoneleigh. There were first visits to the Royal Welsh Show (Builth Wells), the Tyne Fair (Newcastle) and the London Building Exhibition (Earl's Court). As well as promoting services to commerce and industry, these exhibitions offer an excellent opportunity to develop better public relations and to this end the regional and national television weathermen were in attendance where practicable. The Office also advised on the mounting of many static local displays dealing with some aspect of the work of the Office. Other promotional activities included the preparation of brochures and leaflets publicizing individual services.

Direct contact has been maintained with the public by Headquarters staff of the Public Services Branch who reply to the hundreds of letters received every year and who also organize tours by visiting parties around the Operational wing of the Meteorological Office Headquarters. Staff also devote a considerable amount of their own time to the giving of talks and lectures to many interested clubs and societies. A great many enquiries from the media are also handled at the Headquarters of the Office and elsewhere.

Services for marine activities

The offshore oil and gas industries continued to make heavy demands on the forecasting services of the Meteorological Office and greater resources were committed to them during the year. Most of the forecast preparation was carried out at London Weather Centre to which computer forecasts of surface wind and waves were sent on dedicated communication links from Bracknell. The forecasters at the Weather Centre received up-to-date wind, weather and sea state data over a broad area embracing the United Kingdom continental shelf and adjacent waters. By making judicious use of the computer guidance, forecasts were prepared and issued to up to 80 commercial customers at least twice daily. The forecasts, which were usually for periods up to 72 hours ahead, were normally despatched by telex to the shore-based company offices for onward transmission to the offshore platforms, rigs and support vessels. Local forecasting advice was provided on a smaller scale at Dyce meteorological office, near Aberdeen, where the forecasters maintained regular direct contact with the offshore companies through the daily briefing of marine personnel, and at Kirkwall, in the Orkneys, and at Lerwick in the Shetland Islands for the oil tanker loading operations at Flotta and Sullom Voe respectively. The local forecasting offices received guidance from London Weather Centre by facsimile, telex and telephone.

The provision of forecast services in 1982 called for an increase in the deployment of forecasters to the sites of operations. Forecasters worked aboard tugs and other support vessels during the tow-out and installation of several platforms and they were required to give on-the-spot advice for construction work at a number of offshore sites. There was at least one forecaster on duty offshore throughout most of the year and at times there were as many as four. There was a notable achievement at South Brae where Meteorological Office forecasters contributed on the spot to the towing out and installation of a platform within the planned budget in record-breaking time. The Office continued to provide staff and equipment for offshore operators at very short notice. With due regard to the potentially hazardous nature of offshore deployment, all forecasters volunteering for offshore duties completed safety and survival courses at the Robert Gordon's Institute of Technology in Aberdeen during 1982. Services were provided for operations in the Norwegian and Mediterranean Seas as well as for various parts of the European continental shelf. During October and November a forecaster from London Weather Centre accompanied the towing of a converted tanker across the Mediterranean Sea under contract to Shell (International).

Revenue from offshore work increased by about 29 per cent over the previous year and overseas earnings were up by over 40 per cent. A study was made under contract with an oil company of the observational and other requirements for wind and wave conditions to be forecast on Lake Maracaibo in Venezuela.

The Meteorological Office also continued to give technical advice to the offshore industry through its representation on a number of committees. The Principal Meteorological Officer at London Weather Centre was the meteorological adviser to the Oceanographic Committee of the United Kingdom Offshore Operators Association (UKOOA) and the Office also provided a permanent adviser to the Oceanographic and Meteorological Subcommittee of the International Exploration and Production Forum.

The importance of frequent, timely and accurate observations from offshore continued to be recognized by the industry and close collaboration took place with the Office in planning a network of observations making maximum use of modern technology to automate the observational procedures.

Services to shipping via BBC Radio, British Telecom International Coast Radio Stations and our international radio-teleprinter and radio-facsimile broadcasts continued throughout the year.

During the year the British Telecom International Coast Radio Station at Oban was closed down. It was replaced in September by Hebrides Radio which, together with Lewis and Skye Radios, are remotely controlled from Stonehaven Radio. As these stations operate for 24 hours each day, the temporary arrangement whereby gale warnings for the sea areas Rockall and Bailey issued between the hours of 2200 and 0800 GMT were transmitted by Portpatrick Radio was discontinued. Pendennis Radio, a new Coast Radio Station remotely controlled from Land's End Radio was also established during the year. Cullercoats Radio continued to broadcast weather forecasts and gale warnings for all North Sea and adjacent sea forecast areas from Fair Isle to Plymouth in radio-teletype as a temporary service.

Arrangements were made with British Telecom International for the transmission by radio telephony of relevant sections of the Atlantic Weather Bulletin for Shipping—normally broadcast by radio-telegraphy—for the period when the yachts involved in the last leg of the Whitbread 'Round the World' Race were in the areas covered by the Bulletin.

The Central Forecasting Office (CFO) issued forecasts and guidance advice in emergencies involving oil slicks and pollution at sea. The CFO also worked closely with the officers of the Storm Tide Warning Service who continued to be responsible for issuing alerts on occasions when unusually high tides caused by strong winds gave rise to the risk of flooding on the east coast of England.

Pitreavie and Plymouth meteorological offices supplied forecasts for ships of the Royal Navy and Aberporth Meteorological Office provided support for Royal Navy ships undergoing trials in Cardigan Bay as well as answering many general marine enquiries. A winter forecast service for the benefit of North Sea fishing vessels was provided by the Pitreavie Meteorological Office. The forecasts were broadcast daily from October to April and each covered a 72-hour period. Royal Air Force marine craft at home and abroad were provided with forecasts by the nearest meteorological office. The Meteorological Office at Akrotiri provided forecasts for Royal Corps of Transport vessels operating from Akrotiri mole and Gibraltar meteorological office supplied a number of forecasts to ships of the Royal Navy and Royal Fleet Auxiliary.

A ship routeing service continued to be provided to advise on North Atlantic and North Pacific Ocean passages and also to offer advice in regard to the movement of tows and salvage operations. Advice was also given to vessels on passage in other parts of the world on request. In the first part of the year the number of routeings was maintained at a high level but during the summer months there was a fall-off in demand owing to the recession in world trade, the American embargo on steel imports from Europe and the South Atlantic conflict. However, there was an upward trend in the number of routeings towards the end of the year. Continued advertising in maritime publications has resulted in a number of new enquiries and two new large fleet contracts were secured. Of special interest, the weather watch and routeing for the movement of the Thames Barrier gates from Middlesbrough to the construction site by the service in conjunction with CFO was successfully completed in the early part of the year. The voyage assessment service in which an investigation is made into the performance of a ship in relation to the weather encountered during the voyage continued to flourish as more shipowners and charterers became aware of the value of the service in assisting them to resolve claims for slow speeds and other delays in the time spent on voyages.

Services for civil aviation

The term 'civil aviation' covers a multitude of activities which can be divided into two main categories. The first comprises the scheduled services of the world's major airlines, together with those of the smaller feeder companies which serve the more remote areas; the second, known broadly as 'general aviation', most other forms of human aerial activity ranging from private executive flying, through air taxi operations and crop spraying, to club flying and flights by hang-glider or balloon.

The Meteorological Office provides services for civil aviation on repayment as agent of the Civil Aviation Authority (CAA) and in conformity with the regulations of the International Civil Aviation Organization (ICAO). The cost of the services is recovered by the CAA for the greater part as *en route* charges levied on aircraft using the air navigational services within United Kingdom (UK) airspace.

The organization for the supply of meteorological information to civil aviation in the UK is centred on the Principal Forecasting Office (PFO) at London Heathrow Airport. This is also an Area Forecast Centre (AFC), designated by ICAO, with the responsibility for providing forecast information for all flights from Europe to North America. Computer output from Bracknell, modified with regard to the detailed structure of jet streams by specialist upper-air forecasters at the Central Forecasting Office (CFO), is passed to Heathrow. Together with significant-weather charts produced locally at Heathrow, these upper-air charts are distributed throughout Europe by radio and landline facsimile and to United Kingdom recipients by way of land-line Civil Aviation Meteorological Facsimile (CAMFAX) broadcasts. Additionally, certain products from other AFCs which may be needed for long routes are transmitted via CAMFAX. These charts are copied as necessary at airfields to provide aircraft documentation.

This service is adequate for most high-flying commercial aircraft but less well-equipped and lighter planes require more detailed information. Main Meteorological Offices (MMO) at Prestwick, Aldergrove, Manchester and Cardiff support Heathrow in supplying this information either directly or through dependent forecasting offices at other civil airfields. Aerodrome forecasts (TAFs), indicating expected take-off and landing conditions, are provided on a routine basis for most major airfields. Individual route-forecasts are prepared for low-level flights, normally those below 5000 ft, but over Scotland, those below 14 000 ft.

Face-to-face briefing of aircrew is no longer considered essential by most commercial operators and steps were taken during the year to set up self-briefing systems at Birmingham and Manchester, thereby releasing some forecasting staff. General aviation pilots frequently prefer to consult a forecaster, normally by telephone, before making a flight, and this can be very time consuming. To reduce the burden of general aviation forecasting the General Aviation Visual Flight Forecast Service (GAVFFS), an automatic telephone-answering system established by the CAA, is provided. A very limited service for general aviation is being given on an experimental basis through the medium of Prestel, the British Telecom viewdata system.

The supply of forecast grid-point data to British Airways for computer flight planning was extended to cover all the northern hemisphere and that part of the southern hemisphere between the equator and 30°S. The supply of the same data directly to Scandinavian Airlines (SAS) began in the summer. Considerable interest has been shown in the ability of the Office to provide such information and representatives of several large international airlines and flight planning organizations visited Bracknell during the year with a view to arranging its future reception.

A very important aspect of the Office's work for civil aviation is the supply of warnings of weather conditions which could affect the safety of aircraft, either in flight or on the ground. In-flight warnings of certain significant weather phenomena (SIGMETs) are prepared by Heathrow and Prestwick for the London and Scottish Flight Information Regions (FIRs) respectively, and, also by Heathrow, for the Shanwick Oceanic Control Area. Specialized SIGMET warnings are prepared for supersonic civil aircraft within the above areas. All relevant SIGMET information is available with pre-flight documentation and is brought to the attention of aircrews in flight by way of the Air Traffic Control services. Warnings are issued to aerodrome authorities when weather conditions likely to affect ground operations are expected. Accurate warning of commencement, duration and intensity of snowfall plus relevant surface wind and temperature predictions are vital if the costly equipment and materials used in aerodrome snow and ice clearance are to be used effectively and economically, and the financial penalties to operators of aircraft forced to divert to other airfields can be large. The trial of a wind shear forecasting service at Heathrow proved sufficiently successful for a fully operational Heathrow Windshear Alerting Service (HWAS) to be instituted in May. Consideration is being given to extending the service to some other major airports where forecasters are in attendance throughout the day.

Every hour, minimum pressure values for each of 20 Altimeter Setting Regions (ASRs) over and around the United Kingdom are prepared in CFO. These are used mainly to ensure the safe clearance of high ground but, in addition, low-flying aircraft and helicopters use ASR values over the sea to maintain safe vertical separation.

At aerodromes, weather observations are of great importance and Meteorological Aviation Reports (METARs) are made, usually half-hourly, at most civil airports. At airports without Meteorological Office staff, observations are made by Air Traffic Control (ATC) personnel who have been specially trained for this purpose. Courses, consisting of one week at the Meteorological Office College at Shinfield Park followed by one week at a civil aviation outstation, are organized for these sponsored ATC staff on a repayment basis. In most instances, METAR reports are transmitted to the CAA message-switching computer at Heathrow, from which they are retransmitted nationally and internationally by way of the Operational Meteorological (OPMET) teleprinter channels and the Meteorological Operational Teleprinter Network, Europe (MOTNE), respectively. TAFs are similarly exchanged between offices and both, together with area forecast charts or low-level route forecasts, make up the weather documentation provided to departing aircrew. The withdrawal of forecasters in December 1981 made way for the closure of the remote observing office at Cardiff/Wales Airport and the refurbishment of the previous forecast office to house the observers. The move was completed late in the year.

The CAA has continued its investigations, with the active support of the Office, into new types of information system. A trial of a semi-automatic display for weather observations is planned for summer 1983. The system is to be based on one successfully employed on North Sea oil rigs, with the additional manual input of cloud, weather and visibility elements.

One of the tasks of the Civil Aviation section is to provide, on requests from the Accidents Investigation Branch (AIB) of the Board of Trade, detailed weather information which may be relevant to an aircraft accident. The normal requirement is for copies of actual weather reports, relevant forecasts and warnings, and a résumé of the general weather situation. Occasionally, climatological data, such as hourly rainfall are also required. This year was no exception to the norm and several investigations were requested of the weather relating to incidents ranging from aborted take-offs to fatal helicopter accidents in the North Sea.

Two sessions of the National Gliding Championships were provided with forecast services, one at Dunstable in July, and the other at Booker in August.

Two members of the Office's scientific staff, based at the Civil Aviation Authority headquarters, contributed to the examining function of the Directorate of Flight Crew Licensing. As a service to training establishments, occasional bulletins were issued during the year, drawing attention to common errors of candidates. There was a further drop in the number of candidates examined to 1005, the lowest annual total since 1964. Advice on the content, form, and style of future examinations was given to the working group on Senior Licence Examinations. Revision of the Meteorology section of the Air Traffic Control training manual continued and completion is expected in early 1983. A start was made on a draft revision of the meteorological content of an ICAO training document. A meeting of the Communications and Meteorology Division of ICAO conjointly with the Commission of Aeronautical Meteorology of the World Meteorological Organization recommended Bracknell as the site for one of the two World Area Forecast Centres (WAFC) to be set up under the new Area Forecast System. Bracknell was also chosen to be one of the three Regional Area Forecast Centres (RAFC) proposed for the European Region. During the last three months of the year, consultations with the other centres in Europe have gone a long way to formulate the method of providing the required services within the region, described in the *Annual Report* for 1981 (page 22), and the ways of exchanging the forecasts both within the region and with other regions. A meeting of the Meteorological Advisory Group (METAG) of the European Air Navigation Planning Group (EANPG) of ICAO was held in Paris in September. A member of the Office attended this meeting as an adviser to the CAA and also attended the working group set up to study meteorological services for offshore helicopter operations (primarily over the North Sea).

Services for civil aviation and the general public (overseas)

Services for civil and general aviation were provided from the meteorological offices at Royal Air Force Gibraltar, Gutersloh and Wildenrath. At Gibraltar meteorological services were also provided for the general public through the media of the Press, radio and television, and for various civil departments and commercial concerns. The services were provided in accordance with charging policies for similar services in the United Kingdom. In Cyprus, services to the public from the meteorological office at Royal Air Force Akrotiri were limited to forecasts broadcast by the British Forces Broadcasting Services (BFBS). A similar service in Germany was provided by the meteorological office at Royal Air Force Wildenrath. Close contacts were maintained with the Cyprus Government Meteorological Service.

Services for the Royal Air Force

Senior officers of the Meteorological Office fill the posts of Chief Meteorological Officer on the Air Staffs at Headquarters Strike Command (HQSTC) and at Headquarters Royal Air Force Germany (HQRAFG). They are responsible for the provision of meteorological services to meet the requirements of the Commands and act as meteorological advisers to the Commanders. Meteorological services for the Royal Air Force in the United Kingdom including the Royal Air Force units at the MOD(PE) airfields at RAE Farnborough, RAE Bedford and the Aeroplane and Armament Experimental

Establishment at Boscombe Down, are provided by offices organized partly in conformity with the Royal Air Force command and control organization.

The Principal Forecasting Office (PFO) at HQSTC, continuously manned by senior forecasting staff, exercises technical control over the output from the subsidiary forecast offices at all the airfields under Strike Command, in RAF Germany and at several airfields under Support Command. The forecast products from the PFO are used by the subsidiary offices to assist in meeting the requirements of military aircraft operating in widely differing roles, from fast jet to transport at both high and low level. With the aim of achieving greater efficiency and flexibility in responding to the Royal Air Force requirement a computer system, linked to the central computer resources at Bracknell and known as the Outstation Automated System (OASYS), became operational in the PFO at HQSTC in January. Work has continued on the development of the system and its extension to Remote Outstation Automated System Terminals (ROASTS) capable of providing improved support for the forecasters at the subsidiary forecast offices.

Main Meteorological Offices (MMOs), manned 24 hours a day are located mainly at Royal Air Force Group or Maritime Air Region Headquarters. The location of the MMOs within separate regions of the United Kingdom allows expertise in regional meteorology to be applied not only to services for Defence but also for civil and general aviation, industry and commerce and for the general public. During the year a joint study has taken place with the Air Force Department on the future role of the MMOs in relation to the needs of the Royal Air Force. As an outcome of this changes of role in 1983 and 1984 are foreseen for some meteorological offices in north-east England and in East Anglia.

The major part of the routine support provided for the subsidiary offices by the PFO at HQSTC is in the form of a comprehensive routine program of analyses and forecasts in chart form transmitted by facsimile which are designed to cover most of the operational requirements of the Royal Air Force in the United Kingdom. Additional routine facsimile products are broadcast to selected offices by the MMO at Headquarters 38 Group Royal Air Force. A dedicated teleprinter broadcast from the PFO to the subsidiary offices contains both actual and forecast data relevant to the task. The personal briefing of aircrew and operational staff and the provision of shorter-period subjective forecasts is well supported by dedicated facsimile and teleprinter broadcasts. The powerful computer system at Bracknell provides major support, using existing meteorological communications, to all the offices serving the Royal Air Force in the United Kingdom and overseas through the automated selection and transmission of large amounts of data and the provision of forecasts up to five days ahead.

Defence requirements for meteorological support in the Mediterranean are provided by the MMOs at Royal Air Force Gibraltar, Royal Air Force Akrotiri and by an observing office at Paphos in Cyprus. At Gibraltar the radiosonde unit maintained a routine program of radiosonde and radar wind observations for the international upper-air network whilst staff of the observing office at Paphos undertook a routine program of pilot balloon ascents. In Europe, following a critical review of the organization required to provide meteorological support to British Forces in Germany, the MMO at JHQ Rheindahlen closed on 29 January, almost twenty years after its transfer from Wahn in 1962. Royal Air Force stations Wildenrath and Gutersloh commenced continuous forecast cover from 25 January and at all our subsidiary forecast offices in Germany increased use is now made of host-nation resources in addition to technical support in the form of a dedicated facsimile broadcast of charts, analyses and forecasts from the PFO at HQSTC. Only minor problems, mainly associated with the complex communication links involved, occurred during the reorganization. The staff savings resulting from the change totalled 14 Meteorological Office staff and 5 Royal Air Force teleprinter operators.

The staffs of the meteorological offices at the Royal Air Force airfields in Germany were fully involved in NATO evaluation exercises during the year and invariably achieved high markings. Staff from the Gutersloh office were deployed in support of Harrier operations on a number of occasions.

The VOLMET voice broadcast of plain language reports from a selection of Royal Air Force, USAF and civil airfields continued to be provided from the London Military Air Traffic Control Centre at West Drayton. Data for the broadcast are processed and supplied directly from the automated Telecommunication Centre at Bracknell.

The Office contributed to the training of military aircrew by the provision of lectures in meteorology and tutorial assistance, mainly at the Support Command training airfields where potential aircrew receive their first experience of support for their tasks from Meteorological Office staff.

Services for Defence in the Falklands conflict

The Meteorological Office responded promptly and successfully to the many extra and varied demands from the Ministry of Defence and all three Services for meteorological support throughout and subsequent to the Falklands conflict. The importance of meteorological support to MOD and to all three Services in mounting such operations in adverse weather was clearly demonstrated and well recognized. Many Headquarters Branches and outstation offices were directly involved and long hours were voluntarily worked by staff, often at short notice.

It was recognized that forecasting for the South Atlantic would prove very difficult in the absence of reliable computer forecasts directly related to Defence needs in the Southern Hemisphere. Considerable programming effort over the weekend of 3 and 4 April resulted in southern hemisphere forecast charts, on a projection centred on the area of interest, becoming available both for the surface and for a number of upper levels twice daily as an operational routine some four months ahead of the planned schedule for the introduction of the global model into routine use. Very few adjustments were subsequently needed and experience rapidly showed that a high degree of confidence in the products was justified. A large number of enquiries for climatological advice were also received and a detailed brief on the climate of the South Atlantic throughout the year was issued.

Close contact was maintained with Air Force Operations in the MOD Defence Situation Centre, with the Fleet Meteorological and Oceanographic Officer and the Fleet Weather and Oceanographic Centre (FWOC) at Northwood and, later in the conflict, with HQ United Kingdom Land Forces at Wilton. The computer products and their interpretation by the CFO forecasters were of major assistance to the FWOC forecasters in their support of Commander-in-Chief of the Fleet (CINCFLEET).

The first Mobile Meteorological Unit (MMU), manned by Meteorological Office staff in uniform, was deployed to Ascension Island on 8 April and the second MMU was deployed to the Falklands on 13 July. A remarkable feature of both deployments was the readiness with which the MMU staff and their colleagues responded to the call for their services. The Meteorological Office is not complemented for MMU manning so that the deployments affected not only the MMU staff but required that many of their colleagues worked long hours in covering their absences. The MMUs were both still in position at the end of the year.

Services for the Army Air Corps
Meteorological services for the Army Air Corps continued to be provided by subsidiary forecast offices at Netheravon and Middle Wallop in the United Kingdom and at Detmold in Germany where the Senior Meteorological Officer carries additional responsibilities as the Senior Meteorological Officer at the Headquarters of 1(BR) Corps at Bielefeld. He and his staff supported Army deployments in the field throughout the year.

Other services for the Army and Establishments of the Ministry of Defence Procurement Executive
Meteorological offices were maintained at the Royal School of Artillery, Larkhill, at the Royal Aircraft Establishment (RAE) Aberporth and at the Proof and Experimental Establishments (P & EE) at Shoeburyness, Eskmeals and Pendine. The office at Larkhill also provided meteorological support for the Chemical Defence Establishment (CDE) at Porton Down and for RAE and P & EE units located at the ranges on Salisbury Plain. At Aberporth there was a very significant increase in demand for meteorological services during the spring and early summer, arising from an upsurge in the number of guided weapon trials in support of the Falklands Task Force. Also supported were special NATS trials concerned with precision altimetry and aircraft separation. The Shoeburyness office continued to support the Atomic Weapons Research Establishment at Foulness and RARDE at Potton Island.

Meteorological Office support was provided for the Royal Artillery practice camps at Sennybridge, Otterburn and Okehampton for several periods throughout the year. Forecasts were provided for parachute dropping zones (DZs) throughout the United Kingdom. Staff were attached to the rocket range at South Uist in the Hebrides to provide assistance for a program of missile firings during the summer. Several Defence establishments were supplied with meteorological data and advice connected with the development of weapons and military equipment. Joint trials for the assessment of explosive sound propagation and focusing were held at Porton Down in the spring and again in the autumn. Defence Services Branch HQ staff, scientists from the University of Salford and staff from the meteorological office Larkhill participated in the trials with logistic support provided by CDE. Trials directed towards improving wind-finding techniques in the lowest levels of the atmosphere were also conducted at Larkhill and Eskmeals.

Liaison with the Royal Navy
Close co-operation in Defence matters was maintained with the Directorate of Naval Oceanography and Meteorology (DNOM), mainly through the

post of Naval Liaison Officer (NLO) in the Headquarters of the Meteorological Office at Bracknell. Co-operation in the organization and development of national and NATO meteorological support between the Meteorological Office and the Royal Navy ensures an efficient across-the-board response to United Kingdom Defence requirements for meteorological support for land, sea and air forces both nationally and within NATO.

International Defence Services

The Meteorological Office participated actively on behalf of the United Kingdom, in the work of a number of NATO groups concerned with the co-ordination of meteorological support for military and civil defence needs and also contributed to studies associated with that support. The co-ordination of Meteorological Office activity in NATO exercises is centred in the Defence Services branch, working closely with DNOM through the NLO. The national and NATO roles of the Meteorological Office in transition to war and in war are kept under constant review and a member of the Defence Services Branch represents the Meteorological Office on the Air Force Department Steering Committee for WINTEX-CIMEX exercises.

The Meteorological Office provided, for the United Kingdom, a Principal Scientific Officer with the rank of Group Captain in the post of Chief Meteorological Officer on the staff of the Supreme Allied Commander at SHAPE. The Officer also contributed one forecaster and two assistants to the staff of the NATO Allied Meteorological Office in the Joint Operations Centre at Maastricht in Holland.

Services to the Home Office

Detailed planning to meet the meteorological requirements of the United Kingdom Warning and Monitoring Organization (UKWMO) continued throughout the year. Forecasters were provided for the meteorological cells in the five Sector Controls during the international exercise held in March. The Meteorological Office also supplied the charts and data for the exercise weather to be used by all nations planning to participate in the NATO Civil Defence exercise WINTEX in 1983. Lectures on the Meteorological Office organization related to fall-out monitoring were given to UKWMO Sector Control staff, warning officers and the Royal Observer Corps.

Services for nuclear establishments

Arrangements for MMOs to supply information to nuclear establishments of the United Kingdom Atomic Energy Authority, British Nuclear Fuels Ltd, AWRE and the Electricity Generating Boards in the event of the accidental release of radioactive or toxic material, were kept under constant review and frequently exercised. Similar arrangements cover emergencies which could arise in the transport of radioactive material or which might involve nuclear submarines in port.

Climatological Services

General climatological matters are the province of the Climatological Services Branch and include the archiving of climatological data (apart from rainfall and radiation), the production of publications using these data and the provision of enquiry services. Many enquiries yield revenue, and income has continued to rise at a higher rate than staff costs. Revenue from all climatological enquiries, including those handled by the Agriculture and Hydrometeorology Branch, has more than doubled since 1979 exceeding £260 000 this year. Table XIII provides a detailed breakdown of the various types of enquiry handled.

Climatological data

The numbers and geographical distributions of the various types of station supplying data for climatological purposes are summarized in Table IV. Included are official Meteorological Office synoptic stations, auxiliary synoptic stations, and co-operating voluntary climatological stations. The Meteorological Office is indebted to the very many co-operating observers who provide much valuable information which could not be made available economically in any other way. It is a matter foı some concern that there was a net loss of 29 voluntary observers over the year.

The major task of quality controlling climatological data is undertaken partly by use of computer techniques and partly subjectively. Computer checks are made on the raw data for such matters as internal inconsistencies, impossible values and, where possible, sequential consistency. After initial queries have been resolved, further checks compare data from all climatological stations on an areal basis and corrections are made where necessary. Queries raised at each stage by the programs are referred to staff at Bracknell (for England and Wales), Edinburgh (for Scotland) and Belfast (for Northern Ireland). Quality control of climatological data is necessary to maintain the archive to a high standard, and it is especially important in answering the many enquiries of a legal or insurance nature.

Increasing use was made of microfiche for storage of data. After observations have been quality controlled the data are written to fiche for use by the enquiry bureaux at Bracknell, Belfast and Edinburgh. Observations from the 50 stations previously published in the *Daily Weather Report* are decoded by computer programs and written to microfiche soon after the data are received and before quality control. These data are issued to various customers weekly, monthly or quarterly, and are also used for international library exchange purposes. The final issue, containing 3 months' data for 50 stations, can be written to a single fiche. Similarly, upper-air data, which used to be reported in the *Daily Aerological Record*, are also written to microfiche.

Land climatology

The Land Climatology section is responsible for the production of publications and provision of enquiry and consultancy services. Increasing attention was given to consultancy work since this enables potential users to receive advice on the most efficient use of climatological data and, where appropriate, to be given the opportunity of having Meteorological Office expertise applied to their particular problems. The increasing emphasis on a commercial approach to the sale of information and advice has led to the need for more consistency in the application of policies regarding charging.

Not surprisingly a very large number of enquiries resulted from the exceptionally cold weather which occurred during December 1981 and January 1982. As a result, studies into the probabilities of occurrence of extreme events, particularly those of low temperatures, were undertaken in a similar fashion to the strong wind analyses already available and much used by engineers and planners. Specific 'cold weather' enquirers included the Department of the Environment in connection with the restricted flow of diesel fuel, a manufacturer of equipment designed to overcome this problem, and the Department of Health and Social Security for advice on ways of identifying those occasions which might lead to special hardship for claimants of supplementary benefits.

Consultancy services were provided to Government Departments, public bodies and private industry. One particular consultancy was for British Telecom, for whom an investigation into the frequency of strong winds at Goonhilly Down was useful in the determination of design and management strategies for their world-wide communication systems. Another consultancy was with the Department of the Environment concerning the fog susceptibility for part of the proposed extension to the North Circular Road around London.

Interest in alternative energy sources resulted in a contract being obtained from the EEC to provide information to be used in the preparation of a wind energy atlas for Europe. Another project involved the supply of a quantity of data to the Science and Engineering Research Council for the study of various aspects of energy conservation in buildings.

The increasing use of computers by schools and colleges gave an increased number of requests for data to be used in computer science course projects. An approach was made to Education Authorities pointing out the potential problems (both of cost and data availability) and making suggestions to overcome them.

Building and construction climatology

Two posts established to study building climatology, and previously wholly funded by the Building Research Establishment (BRE), were the subject of revised financial arrangements. Strong links will be maintained with BRE but it will be possible for the Branch to devote more time than hitherto to the improvement, provision and promotion of Meterolological Office services for the building and construction industry.

Collaboration with BRE proceeded on several studies linked to the revision of British Standards Institution Codes of Practice. Foremost among these were those concerning the exposure of buildings to driving rain and the loading of buildings by snow and wind. Work on a driving rain index was presented at the International Symposium on Building Climatology held in Moscow in September.

Publicity for climatological and forecasting services available to the construction industry was achieved by means of articles and lectures, a talk at a workshop on data for energy-conscious designers and by a display at the London Building Exhibition at Earls Court in October.

Marine climatology

Despite the recession there was a continuing steady flow of enquiries concerning the design, planning and implementation of marine projects. A trend to larger, more complicated investigations resulted in increased revenue although the total number of enquiries has decreased. The range of enquiries received was very broad. At one end of the scale, an assessment was made of the severity of weather conditions affecting an oil terminal jetty with a high financial penalty should operating restrictions be too stringent. At the other end of the scale, wind data were provided for research workers interested in the migration of early man across the Timor Sea to Australia. A fairly large amount of work was undertaken for the Ministry of Defence and for contractors working for MOD, particularly around the time of the Falklands crisis.

A major project completed during the year was the Meteorological Office contribution to a joint investigation with the National Maritime Institute. This concerned the modelling of wave climatology and made use of visual estimates of winds and wave heights by deck officers of the Voluntary Observing Fleet. The Meteorological Office contribution was an assessment of the accuracy of winds from these ships, and a paper was published in the *Meteorological Magazine.* Two other large projects came to a successful conclusion: in one project meteorological observations from all the North Sea oil platforms were summarized, and the other concerned an assessment to be made of wind as an offshore energy resource.

Advice on matters concerned with safety offshore was provided through the Department of Energy and the British Standards Institution; the marine climatologist acted as a panel member during the discussion phase of a one-day symposium centred upon the new Code of Practice (BS 6325) for fixed offshore structures.

The global archive of surface marine meteorological data was agumented during the year by receipt of all data from the areas of responsibility of the Netherlands and Hong Kong. Data from the Federal Republic of Germany are also to be received, but are not expected to arrive until spring 1983. Attempts to establish similar exchange agreements with Japan have proved unsuccessful so far.

Work on the revision of sea ice and ocean current sections of the Admiralty *Pilots* continued and four volumes were revised during 1982. In the early part of the year operational work on sea ice was transferred to the Marine Division of the Office.

Investigations and development

Work was completed on a statistical model which generates a time series of hourly mean wind speeds. The model provides a method of calculating extreme values and probabilities of spells of wind speeds above or below given values and can now be applied to any location in the United Kingdom. Part of this work led to the formulation of an index of wind strength which can be used, for example, to assess the historical variation in the wind energy resource. By the use of pressure data, values of this index were calculated on a yearly, seasonal and monthly basis for the past 100 years.

The application of extreme-value theory to climatological parameters was examined to see how well the requirement for adequate sampling in the theory is achieved in the climatological observations. Difficulties were found whenever extremes resulted from more than one factor and whenever the element being studied was one which showed marked seasonal variations. In the latter case the extraction of extremes on a monthly basis can cause problems because of the small sample size.

Publications

The publication of the *Monthly Weather Report* containing summaries of observations for most of the stations in the climatological network has continued. Work began on programs to produce the tables in this report using mechanical chart plotters rather than microfilm techniques. The opportunity will be taken to make the programs more robust and more capable of being adapted to meet changing circumstances. The advantage of a chart plotter is that reduction to page size rather than enlargement from microfilm will lead to a better-quality product.

The volume for Africa of *Tables of temperature, relative humidity, precipitation and sunshine for the world* is now with the printers. This is the third volume of the series to be completed.

Work on several more of the regional *Climatological Memoranda* is well advanced. The Introduction to these memoranda (CM 113) was published this year.

Services in Scotland and Northern Ireland

The main functions of the Edinburgh office are the provision of an enquiry bureau specifically for Scotland and the subjective element of quality control for Scottish data. There is, of course, close liaison with Bracknell staff who maintain the climatological computer archive, and develop and run programs for enquiry and quality control work. The manuscript archive of original data for Scotland is in Edinburgh. The Superintendent and her staff also look after some of the Scottish aspects of work of the Observational Requirements and Practices Branch and of the Agriculture and Hydrometeorology Branch.

Since 1960 there has been a similar, but somewhat smaller, office in Belfast fulfilling the same role for Northern Ireland. Accommodation and some ancillary services are supplied by Northern Ireland Departments in exchange for climatological and meteorological services. During the year the office moved to new premises near the centre of Belfast (see Plate V).

These two offices use manpower more efficiently than would be the case with complete centralization at Bracknell since the staff answering enquiries and scrutinizing the data have first-hand and specialist knowledge of the meteorological and climatological problems of their respective areas.

Services for Hydrometeorology

The hydrometeorological services provided by the Meteorological Office depend upon the ready availability of good-quality data held in computer data banks in a form suitable for processing to meet the many varied requirements of both customers and the Office. The system relies upon the co-operation of water and other authorities throughout the United Kingdom, who operate most of the network of around 6000 rain-gauging stations for the supply of basic data.

Following the 1981 annual meeting between the Meteorological Office and the National Water Council (NWC) at which liaison between the Office and representatives of the water industry was reviewed, a small working party was set up to recommend future procedures to provide and maintain national rainfall data archives for both standard (manually taken) daily rain-gauge observations and data from rainfall recording instruments. The working group was chaired by a representative of the Director of Operations Group of the NWC, whilst the Office provided the secretary. The group met several times during the year. Their report recommended a reduction in the national rainfall observing network of standard (daily read) gauges but an increase in the number of reports contributing to an archive of data over intervals much less than a day. The terms of reference of the group were limited to England and Wales, but the Meteorological Office kept the relevant bodies in Scotland and Northern Ireland informed so that the possible effects on rainfall data gathering and archiving in those countries did not go unnoticed.

The routine collection of rainfall observations from various sources was continued. A new arrangement to identify and hasten missing data was introduced. A review of the existing procedures at Bracknell for quality control of daily rainfall observations was undertaken in order to reduce further the manual effort needed to follow up the initial computer examination and correction of data. The meteorological offices at Belfast and Edinburgh continued to collect and monitor rainfall observations from Northern Ireland and Scotland respectively and to contribute to the national rainfall archive held at Bracknell. The data bank of hourly rainfall accumulations provided by recording gauges of various kinds was maintained, though attempts to extend the network of stations contributing to this archive were largely frustrated by the standard of instrument maintenance required which many co-operating observers found difficult to attain.

The Meteorological Office computerized index of rainfall stations, Rainmaster, was maintained and used as the control data set for most of the data entry into the computerized archives. Copies of the index were provided to water authorities and to certain Weather Centres to help them determine the availability of data for members of the public. Liaison concerning the index continued with the Water Data Unit and the Institute of Hydrology.

The publication *Monthly and annual totals of rainfall for the United Kingdom* was issued for the years 1975, 1976 and 1977, thus reducing the backlog attributable to printing difficulties in previous years.

This publication serves as a convenient national summary for official purposes and is exchanged with a large number of meteorological services in other countries. It is sold in the UK to university and other specialist libraries and also to members of the public.

The number of enquiries continued to show a decline in 1982, following the peak in the autumn of 1980, although more requests were received for output from the suite of computer programs for drainage design work based on the Flood Studies Report. Enquiries were received from a variety of sources including the building industry, the legal profession, municipal and consulting engineers, water authorities and educational institutions, and covered a wide spectrum of interests. In order to answer these enquiries a considerable amount of rainfall data has been written to the microfiche archive held in the enquiry section. This archive contains all available monthly, daily and hourly rainfall values since 1961.

Assessments of total areal rainfall month by month for approximately 900 catchment areas in Great Britain were completed up to the end of 1980, together with an account of the rainfall, evaporation and soil moisture deficit during 1980. These items were prepared for inclusion in the Department of the Environment Water Data Unit's publications *Water data 1980* and *Surface Water: United Kingdom 1977–1980*. The geographical boundaries of the areas used in the *Monthly Weather Report* and some of the water authority areas were digitized as an aid in the routine calculation of monthly areal rainfall values.

Computer programs were written to extract data from the new National Climate Message for inclusion in the weekly estimation of variables of the soil water balance by the Meteorological Office Rainfall and Evaporation Calculation System (MORECS). Most of the preparatory work was completed for the construction of a MORECS-derived archive of evaporation and soil moisture deficit data from 1961 onwards. Both agricultural and hydrological interests will be served by such an archive.

The Meteorological Office maintained an experimental network of weather radars (which covered a large area of England and Wales) and which provided rainfall estimates over small (5 km × 5 km) areas. Techniques were developed for amalgamating the hourly rainfall totals as seen from the individual radar sites, and for totalling these into composite fields of daily rainfall. Archives of hourly and daily radar rainfalls were constructed on a routine basis, starting from 1 January 1981. The methods for combining daily radar (areal) and rain-gauge (point) rainfall totals were refined and the accuracy of the combined rainfall fields was assessed. Methods for combining data for periods of less than a day were developed and shown to give reasonable estimates of the rainfall over small ungauged areas.

The application of the combined rainfall estimates for a number of purposes was studied. A study was made of the potential benefits of using the combined data in answering specific enquiries instead of the routinely available rain-gauge data alone. The greatest benefits to the user are expected when severe local storms, which often occur between the widely-spaced recording rain-gauges, are the subject of the enquiries. A project was carried out to assess the possible use of combined data in the estimations of soil water balance variables and in plant and animal disease forecasts which are made routinely.

Work progressed on a study of the use of radar in rain-gauge network design. The result of this work, carried out jointly with the North West Water Authority, can be expected to provide an alternative view on the size and disposition of the rain-gauge network in England and Wales.

Work on ways to improve the statistics of heavy rainfall events continued. Until now, such statistics have necessarily been based on measurement of rainfall at fixed locations by conventional gauges. The representativeness of such observations has always been a matter of concern. Radar offers an alternative approach that should produce answers that are more accurate and more helpful to hydrologists and meteorologists alike, since rainfall events over areas and catchments can be monitored continuously in time and space.

From the characteristics of the radar rainfall observations (rainfall intensity, movement, distribution) the required statistics can be derived in a new way. A preliminary study showed that storm cells observed by radar in the atmosphere produce 'exceptional' rainfall more frequently than expected from observations made with a sparse, open network of point gauges at the ground. The statistics (probability distributions) of storm movement are therefore likely to play an important role in determining the probability of a given rainfall amount occurring over a given area in a given time. Work to establish those atmospheric variables which influence the efficiency with which storm clouds release their precipitation went ahead in collaboration with other Branches of the Office. When these are better quantified the results of a numerical model of cumulonimbus cloud will be used to revise estimates of the heaviest rain likely to fall in a given interval of time. Such a quantity (Probable Maximum

Precipitation) is required for the design of hydrological structures for which the risk of failure must be low. A statistical study was made to determine whether areal measurements of rainfall by radar can be used to infer the occurrence and amount of rainfall at specific locations.

In the field of international collaboration responses were provided to questionnaires initiated by Rapporteurs and Working Groups of the WMO Commission for Hydrology. Liaison was maintained with the Institute of Hydrology which accommodates the UK National Reference Centre for HOMS (Hydrological Operational Multipurpose Sub-programme), the WMO referral system for information and technology transfer developed for the benefit of developing countries.

Services for Agriculture

A major reorganization of the Meteorological Office resources allocated to the direct support of agriculture in England and Wales was initiated during 1982. Support has been given in the past through small teams of meteorologists at certain Regional Headquarters of the Agricultural Development and Advisory Service (ADAS) of the Ministry of Agriculture, Fisheries and Food (MAFF), with assistance from a larger unit at Bracknell. In 1981 reduction in the number of ADAS regions to six (including Wales) gave for the first time the opportunity to locate agricultural meteorologists in all the regions. Proposals to implement these changes were accepted by MAFF during the year, following staff inspections at existing units. An office was set up at Wolverhampton early in 1982, complementing those already operating at Bristol, Cambridge, Harrogate and Reading. It was agreed with MAFF that a further unit should open in Aberystwyth early in 1983. General agro-meteorological enquiries in Scotland, following the closure of the specialized unit in Edinburgh, and in Northern Ireland were handled by the Climatological Offices in Edinburgh and Belfast, with more specialized queries passed on to agro-meteorologists at Bracknell.

Meteorologists at the ADAS centres worked closely with ADAS advisers on a wide variety of agricultural problems in which the application of meteorological experience and the principles of environmental physics could expedite solutions. Staff in the Headquarters unit at Bracknell assisted those at the outstations by supplying a variety of processed meteorological data from the climatological data bank. The Headquarters unit also maintained a number of operational services including daily messages to plant pathologists indicating the expected development of a number of plant diseases, weekly summaries of meteorological data, and weekly estimates of evapotranspiration and soil moisture deficit for various crops.

The task of the agro-meteorologist is not only to provide advice on all weather-related aspects of agriculture, but also to strive continually to improve the quality of this advice. Both Headquarters and outstation staff again spent a significant part of their time on research investigations the outcomes of which were expected to improve both operational advice from meteorologists and the recommendations emanating from ADAS generally. The range of specialist knowledge required to carry out such work was often larger than could be supplied by an agro-meteorologist alone, and many of the investigations involved collaboration with workers from other organizations. In 1982 studies were carried out in conjunction with the Grassland Research Institute, National

Institute of Agricultural Engineering, Animal Virus Research Institute, Central Veterinary Laboratory, Rothamsted Experimental Station, Institute of Hydrology and others, in addition to those with ADAS staff.

A substantial effort was again devoted to a number of aspects of crop protection. Following a further season of successful tests of the Crop Disease Environment Monitor (CDEM) developed jointly with the Operational Instrumentation Branch, licences to produce the device were granted to several manufacturers. Arrangements are in hand for ADAS to purchase 11 CDEMs for further, more extensive operational trials.

An improved model of Potato Blight development in response to weather was introduced operationally during the year. This replaced the method based on the Beaumont scheme used previously to provide plant pathologists with regular advice on expected disease development. Studies on aphids (which are widespread pests of many crops and also vectors of many diseases) included effects of severe weather on overwintering, and the timing and magnitude of the spring migration peak. Work on pea moth and cut-worm forecasting continued, and the work provided the basis for operational forecasts issued during the season on when to spray against these pests. Similar investigations continued on a number of other insect pests.

Some fundamental aspects of crop spraying also received attention. Theoretical work on crop spray drift led to papers which advance significantly our understanding of the processes controlling the magnitude of drift of pesticides in both drop and vapour form. An investigation of the time allowed by weather and soil conditions ('weather-windows') for safe, effective pesticide spraying has been extended to include several widely used pesticides. Two members of staff continued to serve as members of the British Crop Protection Council Working Group on Weather and Spray Application and they produced substantial written contributions to the report prepared by the Working Group.

One of Britain's major crops is grass, and it was appropriate therefore that there were two major investigations on aspects of grass production, this work being partly sponsored by the EEC Climate Impact Programme. The larger project involved the Grassland Research Institute as a sub-contractor to the Meteorological Office and was concerned with the effects of climate variation on grass yields. The other investigation dealt with the constraints of climate on the successful field drying of hay. Both projects involved the acquisition of a large quantity of meteorological data from a number of countries in western Europe. Processing of these data into a format suitable for the projects is now well advanced. Substantial progress was also made on the development of the models of production and drying which will use these data.

The grassland projects also used a special United Kingdom Agricultural Data set created from several different data sources at Bracknell. Work on the new data set, which was completed during the year, involved stringent quality-control of the 3500 station years of data involved.

Investigations on cereals included modelling the effects of meteorological factors on growth and yield, and determining the influence of shelter on yield. Results from these and earlier studies on the relationship between weather and yield were used in the development of operational models for yield prediction.

Water, whether too little or too much, is often a critical factor in agriculture, and the treatment of its influence forms an essential part of much of the work of the Agriculture Section.

MORECS (Meteorological Office Rainfall and Evaporation Calculation System), which was extensively revised in 1981, performed satisfactorily throughout 1982. It provided each week a variety of data on evapotranspiration and soil moisture deficits which were used, for example, in the assessment of current irrigation needs. A detailed comparison of MORECS estimates of soil moisture deficits with those obtained by direct measurements with neutron probes was carried out in conjunction with the Institute of Hydrology and it was confirmed that MORECS gives acceptable results in most cases. The basic MORECS scheme was adapted to run with climatological data from the Agricultural data set in order to provide long-term irrigation planning advice for individual farming enterprises, taking account of precise cropping patterns for each enterprise. Another development used a version of MORECS in a numerical model simulating the moisture status of soils at several depths during the autumn. The model, used with climatological data, provided information on the frequency with which soil-engaging operations such as ploughing and harrowing might be carried out without causing excessive soil damage through compaction and this information is an important input to farm planning studies.

Animal health remained a major area of concern. Studies of the airborne spread of foot-and-mouth disease continued, with outbreaks in the spring in East Germany and Denmark being monitored and subsequently studied in more detail. The termination in the UK of vaccination of poultry against Newcastle disease led to a revival of work on the likelihood of airborne spread of that virus. One outcome of this was the identification of topics requiring further investigation by veterinarians. Increasing numbers of outbreaks of Aujeszky's disease in pigs stimulated work now in progress on the potential for airborne spread of this virus also. Other work included the use of meteorological data to predict the development of sheep ticks and the construction in conjunction with the Central Veterinary Laboratory of a trial operational system for timing the emergence of certain parasitic larvae.

A number of investigations of the environment within certain animal and poultry houses were completed, some of them prompted by the severe winter of 1981/82. The benefits of shelter to reduce lamb mortality soon after birth were confirmed in wind-chill forecast trials carried out for several farms in southern England with assistance from forecasters at RAF Benson and at Bristol Weather Centre.

A number of other trial or operational schemes also involved co-operation with the forecasting Branches of the Office. Among them were warnings of soil movement in 'fen blows', warnings of the onset of meteorological conditions leading to sharply increased mortality in broiler houses, and tests of a proposed scheme for reducing the incidence of crop spray drift caused by spraying in adverse meteorological conditions.

A substantial effort was devoted to using an ADAS automatic weather station (AWS) in a number of crop and animal experiments, and developing related data processing facilities. This work demonstrated that, when used properly, an AWS can provide a flexible means of environment monitoring.

Numerous talks and lectures were given during the year to a variety of audiences. Display material was provided for a number of conferences or demonstrations; two of the more important being the Royal Agricultural Show, Stoneleigh and the Royal Welsh Show at Builth Wells.

Activities related to WMO included the production of a report on progress in agro-meteorology in the United Kingdom over the past three years, and participation in the WMO–EPPO Symposium on Meteorology and Plant Protection. Another staff member was invited to lecture in Africa on the use of weather and climate data in the protection of field crops, stored crops and animals and to contribute to a WMO Technical Note on weather and animal health.

Observational Requirements and Practices

The Branch, of which the Marine Division under the Marine Superintendent is a part, is responsible for ensuring that regular meteorological observations of suitable quality are made on land, at sea and in the upper atmosphere at enough locations to meet national and international requirements. It specifies how meteorological sensors and observing systems shall be exposed, states the observing techniques to be employed and arranges for World Meteorological Organization (WMO) reporting codes to be implemented at United Kingdom stations. Regular inspections of observing stations are made in line with WMO recommendations to ensure that approved standards of site, instrumentation and observational procedures are maintained.

The Branch establishes, on behalf of the forecasting, climatological and hydrometeorological Branches, requirements for new or improved observational sensors, systems or practices and conducts field trials to determine their suitability for operational work, optimum procedures for their routine use and the effect of their introduction on the accuracy and comparability of the basic observational data. It liaises closely with the Operational Instrumentation Branch on the specification of new sensors or observational systems and on the design of trials to establish the performance of prototypes.

Surface observations

The networks of land and sea stations, manned and automatic, needed to satisfy observational requirements are continuously reviewed by the internal Working Group on UK Observational Networks. The Branch provides the Chairman and Secretary of this group and new policy documents on networks were issued at the beginning of the year. A new international reporting code was introduced in January and the effects were closely monitored.

For weather analysis and forecasting purposes a fairly uniform network of observing stations is maintained with weather reports made at fixed times in the internationally agreed meteorological code. It is essential that these reports, known as 'synoptic' reports, are transmitted to forecasting centres without delay. At the end of 1982 the United Kingdom synoptic reporting network consisted of 262 manned stations on land, of which 78 made hourly reports and 48 made 3-hourly reports every day. The remaining 136 stations reported less frequently, many closing at night or at weekends and public holidays. Meteorological Office staff manned 84 of these synoptic reporting stations, most of which were located at civil and military airfields. During the year a new Meteorological Office manned station was established at Aviemore, Inverness-shire, to fill a large gap in the synoptic network. 14 stations included in the network were manned by DNOM and USAF personnel and at the remaining 164 stations, known as auxiliary reporting stations, weather observations were made by people such as coastguards, aviation staff, lighthouse keepers and a number of private individuals. Special instruction for such observers in the making and reporting of weather observations was given either on station or at the Meteorological Office College. In addition, 67 non-Meteorological Office stations provided regular plain language reports of current weather near major roads to assist the Office in its forecasting role for transport.

Although they cannot yet give the full range of observations provided by the human observer, automatic weather stations are being used increasingly to supplement the networks in cases where it is difficult or expensive to make manned observations. New Synoptic Automatic Weather stations (SAWS) were installed during the year at 3 sites to add to the existing 9 older automatic stations still in operational use at other land stations. Planning continued for the installation of a further 17 SAWS over the next two years.

Automatic systems are deployed at 10 locations in the seas around the United Kingdom, both in support of general forecasting requirements and of specialized services such as that to the offshore industry. The Branch also maintained its effort to obtain regular, good quality observations from company personnel on board oil and gas platforms and rigs. Two members of the Branch visited offshore installations advising on siting of instruments, giving instruction in observing and reporting, and carrying out inspections.

There is also a requirement for records of meteorological variables to be maintained over long periods at sites which are representative of various types of terrain and urban environment. For such climatological records to be of value it is important that the exposure of instruments at stations are to a common standard and that the sites of such stations remain substantially unchanged for long periods. This is difficult to ensure as the demand on land for development purposes increases near many of the stations, and it was necessary this year to reappraise the Reference Climatological Stations, whose data are required, amongst other purposes, for assessing trends.

Many stations making synoptic reports also submit climatological returns. This year a new code, the National Climatological Message, (NCM) was introduced. This code, together with the new synoptic code, enabled climatological data to be fed directly into the computer-based climatological archive from the telecommunication channels. This has caused a significant reduction in the amount of transcription and conversion to machine assimilable form of these data. At 72 stations manned by Meteorological Office staff and at 83 auxiliary stations these NCM returns covered the whole 24-hour period. About 470 stations, which usually make meteorological observations at 09 GMT only, continued to submit monthly manuscript climatological returns. Most of these stations were operated by local, regional or national authorities, but a number were still operated by individuals on a voluntary basis. Costs involved in maintaining the climatological stations continued to increase. Although a little financial support can be made from Meteorological Office funds towards co-operating observers this is not always sufficient to prevent the loss of some stations; notable losses during 1982 included Perth and Stirling where stations have existed since the 1850s. During the year a new book award scheme was instituted to reward observers who had provided climatological returns of high quality for over 15 years.

A more extensive network is required to determine rainfall distribution for application to the use, control and planning of water resources. About 6000 stations provided data, these being listed by area in Table IV. Many of these stations measured rainfall only, and were mostly maintained by co-operating authorities, usually Regional Water Authorities. The Meteorological Office collected data from those rain-gauges which complied with the accepted standards of exposure and type of equipment and rainfall stations were regularly inspected.

Upper-air observations
The normal program of upper air observations continued at eight stations in the United Kingdom, using the Mk 3 radiosonde, and at Gibraltar using the Grawsonde M60. The *Starella's* upper-air program on station 'L' (57°00'N, 20°00'W) of four complete soundings per day (pressure, temperature, humidity and wind) uses VIZ sondes modified to determine winds by means of NAVAID radio transmissions.

The upper-air program continued, using a mixture of standard and high-altitude balloons (see Table V). A general improvement occurred in the height attained by the standard balloons. The high-altitude balloons, deployed in a selective program to provide information from very high levels, were of uneven quality. Although there was a general improvement in the number of balloons reaching the 10 mb level those at some stations, for example Gibraltar did not reach the heights achieved previously.

Radiation observations
The National Radiation Centre (NRC) at Beaufort Park controls a network of 13 Meteorological Office stations which make measurements of solar and terrestrial radiation. Three stations, (Stornoway, Shanwell and Finningley) were added to the network in 1982. Twenty-three other stations belonging to bodies with an interest in radiation measurements contributed to the Office archives; the number of these supplying hourly, as opposed to daily, totals of radiation increased from five to seven. Extension of the Office network and provision of extra equipment was partially funded by the Commission of European Communities (CEC). Regular visits to all stations were made by NRC staff to ensure a uniformity of measurement practice. Much of the instrumentation is calibrated at Beaufort Park and four modern Kipp pyranometers were acquired during the year to improve the calibration service.

The Meteorological Office stations measure the intensity of both the global and diffuse short-wave radiation falling on a horizontal surface. The NRC and Lerwick Observatory record radiation on inclined and vertical surfaces and, with Eskdalemuir Observatory, also record the direct solar beam intensity. Three stations record the difference between the incoming and outgoing short- and long-wave radiation. All data are recorded on magnetic tape at intervals of one minute.

Eskdalemuir, which is the United Kingdom Background Atmospheric Pollution Monitoring station, was equipped to measure atmospheric turbidity with a sunphotometer. This instrument measures the direct solar beam in four narrow spectral bands defined by interference filters; a second unit has been ordered for the NRC.

An investigation was made, partially under another CEC contract, of the use of the extensive United Kingdom network of sunshine records (which record the duration of bright sunshine) to supplement the relatively sparse network of hourly solar radiation measurements. Progress was made in deriving both the global and direct components from sunshine records.

Several hundred enquiries concerning solar radiation were received from about 50 organizations and data were supplied on repayment; a continued interest in obtaining energy from solar radiation being indicated. Data were supplied to the CEC for comparison with satellite-derived measurements. Active participation continued on the International Energy Agency Solar Energy Programme Group.

Observatories

The Branch is responsible for a wide range of observations made at Lerwick Observatory and the Meteorological Office section of the NERC Observatory at Eskdalemuir. The program at Lerwick includes measurements of ozone, atmospheric potential gradient, air-to-earth current and atmospheric pollution in addition to surface and upper-air observations. The wide variety of measurements made at Eskdalemuir include those of the earth's magnetism, evaporation, atmospheric potential gradient and atmospheric pollution.

Thunderstorm location

Hourly observations, between 06 and 21 GMT, of the bearings of thunderstorms measured by direction-finding equipment at five upper-air stations (including Gibraltar), are processed at Beaufort Park to determine the locations of thunderstorms over western Europe and the East Atlantic (see Table VI). There was an increase of about 30 per cent in the number of locations reported compared to 1981. Since observing techniques have not changed it is concluded that this is due to increased thunderstorm activity.

Runway visual range

The responsibility for inspection and calibration of runway visual range (RVR) installations was transferred to the Civil Aviation Authority and the Royal Air Force at the end of May bringing to an end an association with RVR which began in 1948/49 at the request of the Air Safety Board of the then Ministry of Civil Aviation. Up to May, installations were checked at 25 civil airports and 24 RAF stations in the United Kingdom. Towards the end of the year training was provided for the CAA team appointed to take over the work. A study was made of the stability of RVR calibrations in order to provide advice to the relevant authorities.

User trials and quality evaluation

Long-term assessments of the prototype Synoptic Automatic Weather Station (SAWS) and the Automatic Climatological Recording Equipment (ACRE) were completed. A short-term trial of an automatic weather station designed by Heriot-Watt University, for use on exposed mountain tops, was conducted at Eskdalemuir. An extended operational evaluation of this station in its usual location on Cairngorm summit began. Trials are also being undertaken of cheap commercially available thermometer screens and hand-held digital anemometers.

Automation of the monitoring of data quality from automatic weather stations, whether on land or on marine installations was implemented successfully. The technique is also being applied to monitoring the quality of all pressure observations from stations in the United Kingdom.

Daylight twin-flight comparisons between the United Kingdom Mk 3 radiosonde and the German Grawsonde were made in order to refine the solar radiation corrections applied to temperatures measured by the German sonde which is used operationally at Gibraltar. Comparisons were also made with a boundary layer radiosonde of American design to assess its use in fog forecasting experiments in the United Kingdom. Some triple flights were made and Figure 5 shows values of relative humidity in the lower levels of the atmosphere as determined on a particular occasion. Although three different ways of sensing humidity are used the three sondes agree well in showing an abrupt transition from moist air in the lowest layers to overlying dry air. However, there are systematic differences present and also differences in sensitivity which reflect the long-standing and world-wide problem of determining atmospheric humidity aloft both cheaply and accurately.

A report was prepared on the automatic selection of significant levels from the detailed temperature and humidity data produced by the Mk 3 radiosonde. The work is being extended for use with data patterns produced by other types of radiosonde. The performance of about 450 upper-air stations in the

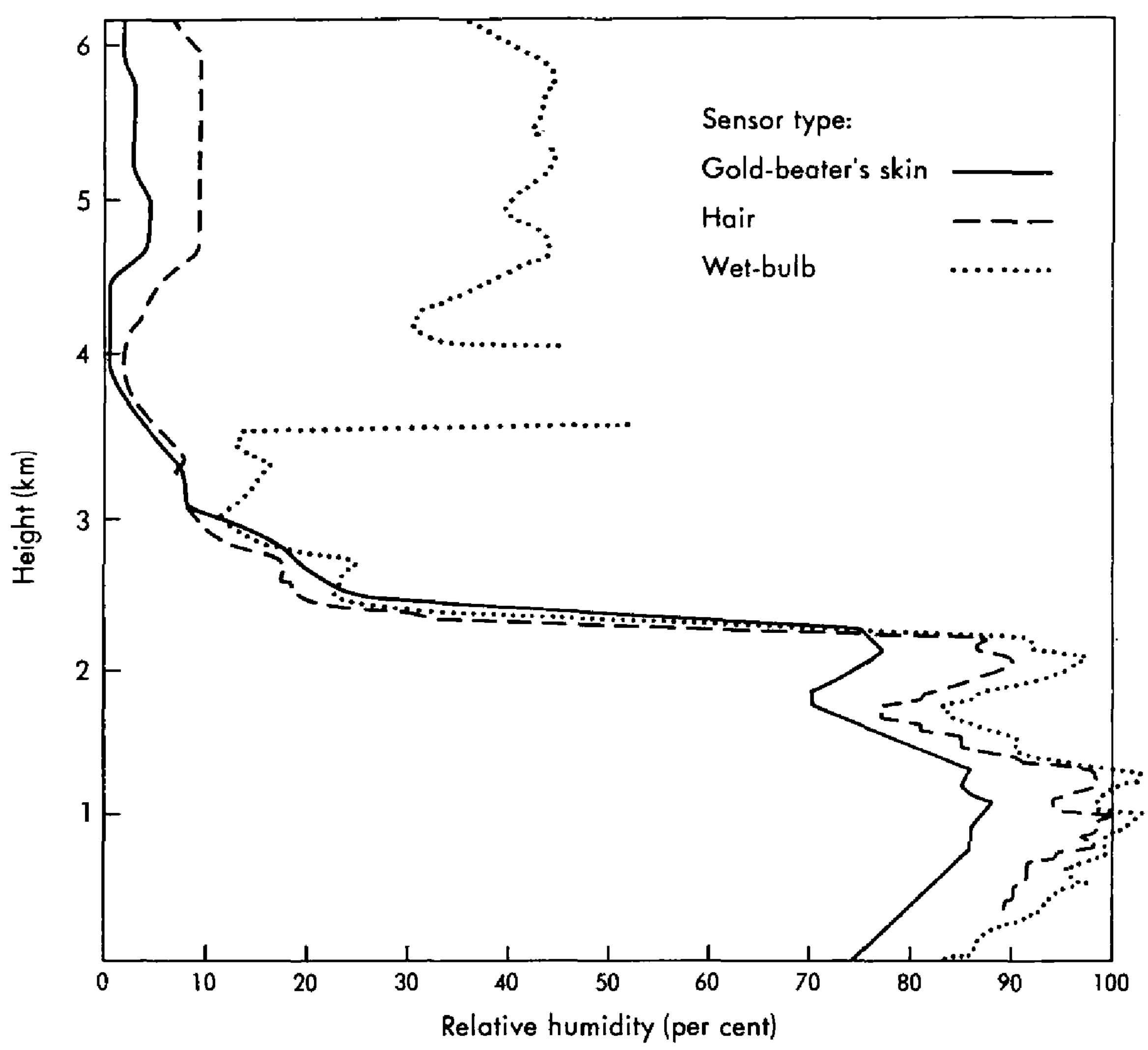


Figure 5—An example of relative humidity values obtained using three different types of sensor during a trial radiosonde ascent

northern hemisphere was monitored during 1981 and the results have been summarized for the World Meteorological Organization.

International matters
In the international field the Assistant Director (Observational Practices) serves on the WMO Working Group on the Global Observing System (GOS) which meets in Geneva. He is also a member of the Study Group on the Manual and Guide of the GOS which keeps these publications under continuous review. Senior Branch members served on the Advisory Working Group on Upper Air Technology of the WMO Commission for Instruments and Methods of Observation and on international Working Groups concerned with radiation measurements, and one acts as a Rapporteur on the compatibility of data from different upper-air measurement systems. The Marine Superintendent serves on the WMO Commission on Maritime Meteorology.

Marine Division
The Voluntary Observing Fleet. The importance of meteorological observations from ships at sea becomes apparent when it is appreciated that the oceans occupy nearly three-quarters of the earth's surface. Apart from HM ships, ocean weather ships and research vessels, surface meteorological observations are voluntarily provided by the masters and officers of merchant ships. In the UK, the Marine Division has been responsible for obtaining these observations since 1855. These merchant ships are collectively known as the Voluntary Observing Fleet (VOF) and they vary from very large oil tankers and passenger vessels to coastal traders and trawlers.

The continued recession in world trade in general, and the depressed state of the shipping and fishing industries in particular, continued to affect the size of the VOF. However, largely owing to the efforts of the seven Port Meteorological Officers who recruit merchant vessels into the VOF and who are established at the major ports of London, Liverpool, Southampton, Hull, Middlesbrough, Glasgow and Cardiff, the reduction in numbers was kept to a minimum. The result was that the percentage of British ships from which meteorological observations were received was greater than ever before. Nearly all the older, conventional vessels of the British merchant fleet have now been replaced by much larger and faster ships which spend considerably less time in port and thus are at sea for a greater proportion of the year. As a result the number of observations received continued to increase.

Meteorological work on board British merchant ships has always been carried out on a voluntary basis and the Port Meteorological Officers, who are all Master Mariners with considerable experience of meteorological observing at sea, are able to contribute significantly to the maintenance of a high standard of observations received from the VOF. With the co-operation of ship owners revised publications were distributed to observing ships all over the world, and the new surface observing code was successfully introduced at the beginning of the year.

The continued trend in the reduction of ships' complements together with efforts to reduce the workload on observing officers led to the installation of distant-reading meteorological equipment in a number of ships under construction. The Port Meteorological Officers received whole-hearted support and co-operation from ship owners in these and other matters to their mutual benefit. Trials continued with the automatic transmission of ships' weather messages.

Many foreign and Commonwealth Port Meteorological Officers continued to give valuable assistance in the replacement of defective instruments and the supply and replenishment of publications and stationery to ships of the British VOF that seldom return home. These officers were also of great assistance in the withdrawal of our equipment from those British ships which were sold abroad.

As usual, the shipmasters, principal observing officers and radio officers who submitted the best meteorological logbooks during the year were presented with 'Excellent' awards in the form of books. Similar awards were made to masters and officers serving on coastal traders for their work in making sea temperature observations. In recognition of their valuable voluntary meteorological work over many years during their careers at sea, four shipmasters were presented with long-service awards in the form of inscribed barographs.

A quarterly journal, the *Marine Observer*, containing articles on marine meteorology and oceanography of interest to mariners, was published as in previous years. The purpose of the journal is to encourage mariners to make meteorological and other observations of general scientific interest and a large portion of each edition is devoted to such observations which are extracted from the meteorological logbooks received from the VOF.

During the year there was an increase in the number of marine enquiries received. These were principally from shipping interests, solicitors, universities and industrial firms and the subjects were extremely varied.

The Ocean Weather Ship service. At the beginning of the year the two British Ocean Weather Ships, *Admiral Beaufort* and *Admiral FitzRoy* were decommissioned and sold and the Ocean Weather Ship Base at Greenock was closed. To meet UK obligations under the North Atlantic Ocean Station scheme the *Starella* (see Plate VI), a trawler which had been converted for North Sea diving operations, was taken on a 4-year time charter during January. After further conversion, she sailed in early February as an Ocean Weather Ship to operate alternately with the Dutch weather ship *Cumulus* on ocean station 'L' situated at 57°00'N, 20°00'W. Concurrently with these new arrangements, the mode of transmission of data from all the Ocean Weather Ships in the scheme was changed to the telex-over-radio communications system. The *Starella* operated out of Fleetwood where a small Ocean Weather Ship office was established.

Station 'L' was manned continuously throughout the year with the exception of 36 hours in September when the *Starella* was delayed in her arrival on station due to engine trouble.

The weather ship made hourly surface and 6-hourly upper-air observations (for heights reached in upper-air ascents see Table V on page 69). Sea and swell records using the Tucker ship-borne wave recorder fitted on board the Starella were made throughout the year. Sea water temperature and salinity readings to within 100 metres of the sea bed, collection of rain water samples for analysis by the International Atomic Energy Agency and collection of sea water samples on passage to and from station for monitoring radioactive content were undertaken at regular intervals. On behalf of the Institute for Marine Environmental Research, a plankton recorder was towed on about half the voyages to and from station during the year.

OPERATIONAL INSTRUMENTATION

This Branch is responsible for the installation and maintenance of all instrumentation needed to meet the operational requirements of the Office. Arrangements are made for new equipment to be developed as and when necessary and technical advice is provided with regard to procurement. In addition, common services such as engineering drawing, mechanical and electronic workshops, technical writing, test and calibration of instruments, photography and technical training are provided and the Office Museum is maintained. The Branch is active in relevant international co-operative activities including 'European Co-operation in Science and Technology' (COST) Project 43 and the WMO Commission on Instruments and Methods of Observation (CIMO) of which a senior member of the Branch is the Vice-President.

The Branch co-operates closely with the Observational Requirements and Practices Branch to define the requirements of the user Branches, and then attempts to meet these requirements by the most cost-effective method. Preference is given to the use of commercially available solutions rather than undertaking in-house design and development. Once the solution to a problem has been found and tested successfully in field prototype form, the Branch provides technical assistance to the equipment supply Branch in the procurement of appropriate quantities of production units. Functionally, the Branch is divided into two parts: 20 per cent of the total manpower form two design and development (D & D) groups; the other 80 per cent form a service, maintenance and support group.

Design and development

During 1982 work was concentrated on sensors for use in hostile environments, and attention was also given to the possibility of extending the range of information which can be obtained from sensor systems operating at remote, unattended sites.

The techniques for protecting humidity devices from attack by halide salts in the atmosphere, especially in marine deployments, were further developed, and a satisfactory operational marine humidity sensor based on the Physical and Chemical Research Corporation (PCRC) element is now available. A new holder which makes mounting the protective membranes more simple and is more suitable for commercial manufacture was developed.

After the completion of laboratory and local field trials, an evaluation program began at Great Dun Fell (near Cross Fell in the northern Pennines) of a Rosemount orthogonal (differential pressure) wind sensor which can operate at high-altitude sites where ice accretion disables conventional wind vane and cup anemometers. Ice accretion, especially rime, is prevented by heating the sensing head. Data are being logged in computer compatible format together with the output from a conventional cup anemometer system which will provide comparison data for periods when icing is not present.

Work continued on the 'weighing tipping bucket' rain-gauge. This device, which measures rate of rainfall and rainfall amount, is intended to provide a replacement for the Meteorological Office tilting-siphon rain recorder which requires manual analysis of its record. The new device was given long-term stability trials during the year with encouraging results and the design of the hardware and software for the intelligent interface to be used in the device is now proceeding. A new approach has been made to the problem of the remote measurement of 'present weather' by using multiple arrays of relatively cheap sensors and processing their outputs by statistical methods to give a best estimate of current weather conditions. For example, a simple device was constructed which measures the local electric field strength and thus gives an indication of the presence of charged clouds. Nearby lightning strikes can also be detected.

Other activities in the sensor development field included the evaluation of a commercial solid-state rainfall logger expected to be suitable as a replacement for the ageing Magnetic Tape Event Recorders (MTER) used for rainfall recording, the development of heated rain-gauges and further development of static pressure heads. A program was also started to construct and evaluate a reference psychrometer to the newly agreed WMO specification.

After some years of difficulties associated primarily with power supplies the four Continuous Automatic Remote Display (CARD) systems at RAF and Army ranges were finally brought into operational service. Some work remains to incorporate the cloud base recorder data into the system and a software controlled interface is being developed.

A second prototype Automatic Climatological Recording Equipment (ACRE) was constructed based upon the lessons learned from the successful field trials with the first prototype. A requirement specification was written and procurement action for 10 systems was initiated towards the end of the year. An interesting problem which was revealed during the ACRE trials concerned a systematic difference between earth temperature values measured by the ACRE electrical resistance thermometers and values from co-located, conventional mercury-in-glass types. Although the differences are small they are significant for climatological purposes, and they demonstrate the difficulty of maintaining homogeneous records when new or alternative sensors are introduced. The Crop Disease Environment Monitor (CDEM) completed a further highly successful season of trials. This microprocessor-based system, programmed to calculate the risk index for a number of weather-dependent diseases of important crops such as potatoes (blight), apples (scab) and barley (brown rust), is now engineered to a commercial production standard.

The three oil platform Automatic Weather Stations (AWS) on Beryl Alpha, Piper Alpha and AMOCO 49–27A were all enhanced with minicomputers and visual display units which allow the manual entry of visual observations, the automatic conversion of data into WMO synoptic code and the recording of data for climatological purposes. Observations from the AWS installed on Sule Skerry Island in late 1981 were accepted for operational use early in the year and the station continued in service throughout 1982 with no major component failures.

The buoy (ODAS 451) funded jointly by Norway, the United Kingdom and Iceland, suffered a mooring failure early in the year. It was recovered, modified to transmit data via Système ARGOS as well as by the original HF system, and redeployed (at 61.5°N, 13.5°W) on 20 July. Observations from this buoy, the first operational ODAS to be deployed under the auspices of the COST 43 project, are available for broadcast on the GTS at 3-hour intervals. The withdrawal of the national data buoy, DB1 (ODAS 10) in March prompted a decision to construct a temporary replacement using, as far as possible, components which were developed successfully for the Lyme Bay buoys (ODAS

1 and 2). It is intended that this replacement buoy (ODAS 20, 1983) will be deployed 150 miles south-west of Lands End until a replacement buoy (DB2) funded by the UK Offshore Operators Association (UKOOA) becomes available, when it will be redeployed in a suitable location in the North Sea.

As part of the program to modify the Mk 3 radiosonde to operate at 400 MHz (made especially urgent following the allocation of the 27 MHz band to Citizen's Band radio) a study contract was let to determine the manufacturing work and costs relating to a 400 MHz flight system. In the interim period, before 400 MHz sondes become available, the existing model was modified to operate at temporary frequency allocations in the 30–35 MHz band. The changeover to this band was effected on 1 January 1982 and this resulted in an almost complete restoration of the operational radiosonde capability.

Experience gained over the first two years of operational use of the Mk 3 radiosonde indicated the need for regular calibration of production batches of the sonde thermometer. This requirement was already foreseen and the necessary facilities were available in the radiosonde calibration plant. A routine calibration system was established on an operational basis and calibrations are now carried out and analysed sufficiently quickly to provide a feedback of information to the manufacturer so as to eliminate manufacturing deficiencies. Work in the Observational Requirements and Practices Branch showed that this calibration process has reduced the incidence of non-meteorological anomalies in temperature soundings to a very low level. The results in general now fall within the consensus of those obtained over Europe and their variance has been reduced about four times compared with earlier results.

Progress was made on the major task of development and procurement of a replacement for the obsolete cathode-ray direction finding (CRDF) system for thunderstorm location. The new system will consist of seven unmanned outstations connected by low speed data links to a control station built around a major minicomputer facility. At the control station the absolute times of the arrival at each outstation of the signal from a particular lightning flash will be compared and the difference between them used to assess the location of the flash. This year, the full hardware and software specifications for the control station were completed and an open tender competition for the supply of the station was held. A contract for the complete system was awarded in November. Significant progress was made in the in-house development of the outstation prototype. All the basic electronic design was finished, and testing, design revision and the production of procurement documents are under way.

Service and maintenance support

The small unit which provides technical support for procurement contracts was again heavily loaded this year. The first 20 Synoptic Automatic Weather Stations (SAWS) and their associated ten polling units were delivered during the year and preliminary work started upon the next phase of this program which will eventually entail the procurement of up to 60 systems. Technical problems experienced by the manufacturer delayed the completion of the contract for the Laser Cloud Base Recorders (LCBR) but the first production prototype was eventually delivered for trials in late November. After the design was approved, deliveries began in December. A total of 20 units are on order.

Contracts are under way for 41 Digital Anemograph Logging Equipments (DALE) of which 26 were delivered during they year, 10 Meteorological Observers Systems for Ships (MOSS) and 22 Mk 5 wind systems. These are all systems which form a part of the program of modernization of instrumentation which the Office is mounting to maintain its observational capability in response to new technical and managerial challenges. The 14 wind finding radars (Cossor 353D) which have been in operational service since the early 1960s are reaching the end of their present operational span. A study contract with Cossor Ltd resulted in a report, delivered this year, in which refurbishment of the radars was shown to be more cost-effective than replacement and contracts for this work were placed late in the year.

Obsolescence is a continuing problem, particularly in the field of electronic components, and the post-design services group was fully loaded devising modifications which enable equipment life to be extended. It is worth noting that work on the problems of obsolescence involves the use of the whole integrated structure of the Operational Instrumentation Branch including the design teams, post-design services, the engineering drawing office, mechanical and electronic workshops, the technical writer and the procurement group.

A reduction in the size of the engineering drawing office group this year contributed to an increase in the amount of external contract work. Six external contractors were used to provide a range of specialist services ranging from computer-aided design to marine engineering. The cost-saving program for the conversion of engineering drawings to 35 mm aperture card format is now complete and all such information is handled this way. The problem of on-site access to drawings data remains to be solved but in all other respects the scheme is now successful. Photography is used extensively as a substitute for manual drafting. To allow installation layouts to be prepared in easily comprehended three-dimensional line composites they are now prepared from original photographs.

Both the mechanical and the electronic workshops had a full workload this year; about 400 jobs were handled by the mechanical workshops at Beaufort Park and London Road. The electronic workshops continued to provide a small-scale modification, repair and construction facility, undertaking work on specialized or obsolete equipment in order to keep such equipment operational in a cost-effective manner.

The first operational SAWS was installed in July and commissioned on 4 August 1982. Further installations followed towards the end of the year although progress was delayed by problems over both site works and telecommunications. The installation and commissioning phases of earlier programs such as the Meteorological Office Data Logging Equipment (MODLE 3), the second round of DALE and the first round of the Mk V wind systems were also completed during the year.

Each new maintenance task with which the Office is faced is analysed to establish the most cost-effective approach. It is then either placed out to contract with an appropriate commercial concern or made the responsibility of the Meteorological Office Maintenance Organization (Met O MO). The number, variety and complexity of the systems inspected, maintained, calibrated and repaired by the Met O MO increased again this year, but continuous improvement in organization and operational practices nevertheless permitted a small contraction in resources. Cost studies carried out upon the maintenance of both the phase III message switching enhancement in the Meteorological Telecommunication Centre (Met TC) and the Automatic Message Preparation Equipment (AUTOPREP) on certain outstations, indicated that Met O MO should assume full maintenance responsibility for these systems as soon as possible. Accordingly plans were made and are being implemented to allow this hand-over to take place next year.

Early in the year, Met O MO staff removed the meteorological instrumentation from the Ocean Weather Ships *Admiral Beaufort* and *Admiral FitzRoy* and reinstalled it aboard the m.v. *Starella*. They were closely involved with the closing down of the OWS Base at Greenock and the opening of the Office at Fleetwood. OWS Office technical support for Fleetwood is now provided from the Regional Maintenance Centre at Aughton.

The School of Technical Training (MOSTT) ran courses on behalf of the Meteorological Office College and details are given in Table XVII. The widespread introduction into operational use of new electronic equipment intensified the MOSTT task of retraining field technical staff. In addition to this 'classroom' training, a total of 30 weeks 'on the job' technical training was given to overseas students during the year.

The work of the Test and Calibration section is, by its nature, routine. This year, activity in the acceptance testing of systems was dominated by work on SAWS and several design and manufacturing problems were discovered and referred back to the contractor for rectification under the provisions of the contract. A steady improvement of throughput due to reorganized working practices enabled the traditional backlog of general meteorological instrument work to be reduced and the program of regular testing and calibration of the electronic test and diagnostic equipment used within the Office to be kept up to date. For the first five months of the year the Mk 3 radiosonde pressure calibration plant was closed down for a major overhaul by Ferranti Ltd and to allow extensive building work to be undertaken on the premises. Stocks of calibrated sensors had been established and the shut-down caused no difficulty. A useful by-product of this situation was that it enabled a check to be made on the long-term drift of a fairly large number of calibrated sensors. It was found that there was no significant deterioration in their performance in this respect. Routine acceptance tests of radiosonde balloons showed a noticeable improvement in their performance over the year which we believe may reflect better quality control by the manufacturer, after our previous test results alerted him to a decline in product quality. The overall totals of instruments, electronic systems and radiosonde components tested or calibrated during the year are shown in Table XV. There was a sharp reduction in the number of radiosonde components and balloons accepted because current contracts were concluded early in the year.

The North West Radar Project in which the Branch was a participant along with the Meteorological Office Radar Research Laboratory and the North West Water Authority, has almost reached the end of its development phase and is virtually an operational system. The new radar/computer interface introduced at the end of 1981 functioned without fault throughout the year and gave a significant improvement in the reliability of the date. The various research sub-projects will collect data until the end of 1982 and reports will be published during 1983. A co-operation scheme involving both Met O MO and North West Water Authority technicians was agreed and implemented to provide emergency call-out cover for the radar which normally operates unattended.

The Heads of Agreement document setting-up the London Weather Radar Project was signed by representatives of the contributing parties—GLC, Thames Water, Southern Water and the Meteorological Offices—in February. Negotiations have since continued to effect the procurement and installation of a Weather Radar system, similar to that in the North West, at Chenies near Rickmansworth. It is expected that the system will be operational by mid-1984. Data from this London Area radar will be fed directly into the GLC Thames Barrier computer as part of the data input for flood control models as well as being incorporated into the Meteorological Office network composite display and providing the other contributing Water Authorities with real-time flood warning data.

Techniques for adjusting the radar data using rain-gauge data were developed by Met O RRL and are now being used at Clee Hill and Hameldon Hill. Extra core store was ordered for the on-site computers at Camborne and Upavon in order that similar techniques may be applied to their data.

Problems associated with interference with British Telecom communication links by emissions from the weather radar on the London Post Office Tower were the subject of discussions with British Telecom, Met O 5 and Plessey Radar, and a simple solution is being sought.

The Meteorological Office/National Water Council Working Group on National Weather Radar Coverage made progress in its task of producing maps of England and Wales showing areas of different categories of flood risk. It is hoped that these maps may be used to determine an optimum network of weather radars to meet the needs of the Meteorological Office and the Water Authorities. Preliminary estimates of the annual benefit accruing from the use of weather radar data in flood forecasting indicate a high level of cost-effectiveness.

International co-operation

Two senior officers of the Branch serve on the WMO Commission on Instruments and Methods of Observation (CIMO). One is Vice President and the other is a member of the Working Group on Instruments and Methods of Observation for Surface Data. A senior officer is Chairman of the European COST Project 43, a Project aimed at establishing an experimental network of real-time ocean data acquisition systems around the European continental shelf.

Computing and Data Processing

Nineteen eighty-two was a year in which further major changes were implemented in the hardware and software on which the central computing system known as COSMOS is based. Following the major enhancement of computing power in 1981 when the CYBER 205 was installed, this machine was progressively integrated into the COSMOS complex. At the end of the year the obsolete IBM 360/195 was replaced by an IBM 3081, a modern machine of similar power. The Office is now equipped with mainframe processors of sufficient speed and capacity to handle the planned workload for some years to come.

Development of the central computing facility

The CYBER 205 was operated on a gradually more intensive scale, a major milestone being reached on 1 September from which date it was used for routine operational forecasting. The machine continued to reach its specified level of performance and its reliability was high. The task of linking the CYBER computer to the IBM processors was found to be more complex than expected and, except for the new operational forecasting work, the 205 was operated through a small front-end CDC machine, a CYBER 170/720, for most of the year. However, the link to the IBM 370/158 began to be used as the means of submitting all CYBER work towards the end of the year. The storage capacity of the CYBER 205 is supplemented by high-density discs, two more of which were acquired during the year. The total capacity is now 3600 million characters, but storage space on these discs continues to be in short supply.

The increased volume of output from COSMOS necessitated the installation of further devices to handle it. During the year a second microfiche recorder and a fourth flat-bed plotter were added. Also, to cater for the gradual increase in the size of the network, a second telecommunications controller was installed. Further development of the terminal system was, however, delayed until 1983, to follow installation of the IBM 3081.

The IBM 3081 is a processor of similar performance to the 360/195. It is, however, equipped with greatly increased storage as well as more channels to link to other processors or peripheral devices, and is compatible with modern software. The 3081 was installed during November, the 195 which after 11 years of service showed some deterioration in performance during 1982 being phased out and made ready for removal at the end of the year. The 3081, while still short of its final configuration, has now been designated the master machine but has not yet been linked to the CYBER 205. Support for the CYBER 205 link now provides the main role for the 370/158.

The changes in hardware in the computer room required several structural and engineering modifications. In particular the eastern end of the room where the CYBER 205 and IBM 3081 are located was partitioned off to allow closer control of temperature and humidity. It is, however, becoming apparent that because of the addition of heat-producing equipment and gradual deterioration of plant, the air-conditioning system for the Richardson Wing as a whole will require replacement in the next year or two.

Systems support

The small group of staff tasked with monitoring and where necessary adding to the software controlling various parts of the computing system was heavily engaged in integrating both of the new processors. The CYBER 205 Operating System as delivered was found to be considerably in need of amendment, and Office staff worked with Control Data Limited (CDL) personnel in identifying and documenting some 100 important errors. A revised version was installed in August. The Systems Group carried out many tests, in collaboration with CDL staff, of the performance and functional capability of the software especially written to link the IBM and CDC machines, and has also been deeply involved in monitoring and optimizing use of the CYBER 205.

During the second half of the year frequent visits were made to the IBM centre at Greenford, Middlesex where a 3081 processor was available for development purposes. A new version of the Multiple Virtual Storage (MVS) Operating System was required for the machine delivered to Bracknell, to enable it *inter alia* to use the new high-speed and high-density storage devices (IBM 3380 discs) to be delivered in 1983. This Operating System was assembled at Greenford in accordance with the required configuration, and incorporates the many local modifications which had been inserted into the previous version of the Operating System since 1978.

The above tasks imposed a heavy work-load on the small Systems Group. They come on top of the routine work which involves the investigation and resolution of problems arising from the operation of the controlling software. A growing commitment is the need to monitor use of terminals to provide assistance to terminal operators when needed.

Support for computer-based applications

The new international reporting codes for surface stations brought into use on 1 January were the first major code changes since automatic methods of data processing and chart plotting were introduced. Extensive trials of the new programs were made and the changeover proceeded smoothly, even though for a while it was necessary to handle messages in both the old and the new codes. Further substantial changes both in the processing of meteorological observations and in the software for producing plotted charts and graphical output were necessitated by the introduction of the new forecast model and extension of the forecast area. A new quality control procedure for upper-air observations is now used to identify and correct erroneous data. The opportunity was also taken to rewrite parts of the synoptic data bank suite of programs in more efficient form. The data bank itself, comprising current meteorological observations received through the Meteorological Telecommunication Centre and stored in processed form, has been greatly expanded in size in recent years. This is due to the increased length of messages in the new codes and to a growth in the number of observations, especially from satellites. Measures are being taken to record the data in more compact form. The schedule of output from graphical devices was greatly changed and expanded by the requirement for charts using different projections, new geographic regions and additional levels.

A small group in the Data Processing Branch is established to train and assist users in programming techniques. As a routine, the group provides training in various aspects of computer usage, and supplies lecturers for courses at the Meteorological Office College. A new commitment is the provision of assistance for users of the CYBER 205. Two courses in CYBER programming have already been given, and numerous enquiries from users have been answered. The replacement of the IBM 360/195 machine by the 3081 was not entirely without effect on users, and changes required in existing procedures were identified and publicized. A new version of the FORTRAN programming language was introduced, appropriate seminars for users being arranged. Monitoring and control of COSMOS usage has been extended to include the use of the CYBER and progressive changes in the allocations of computing resources are being implemented following transfer of the operational forecast commitment to the CYBER machine and the replacement of the IBM 360/195.

Storage and preparation of data

For several years climatological data recorded by hand, usually on prepared forms, have been keyed manually at a Processor-Controlled Keying establishment (PCK) set up for this purpose at Bracknell. It is the intention to automate this process still further and a major step was taken in August, when standard climatological reports were compiled into bulletins at the regional collecting centres and transmitted to Bracknell where they are processed and stored automatically. Though the scheme is still in its early stage—procedures for identifying and correcting errors will, for instance, have to be closely monitored—savings in staff and equipment costs are planned. There will, however, be a permanent requirement to process data such as observations from ships' log-books and similar material. There was a substantial fall in the number of characters keyed at Bracknell during 1982, and increased use was made of the services of a Ministry of Defence keying establishment at Devizes for processing backlog data.

Systems Development

The introduction and further development of automated systems continued to dominate the work of the Systems Development Branch. Effort was concentrated in two broad areas. Firstly, high priority was given to projects which take the benefits of automation further into the outfield. Secondly, increased efficiency was sought through the automation of some support services at Headquarters. These activities have been sustained by the continuing program of installation and enhancement of Outstation Automation Systems (OASYS) and the replacement of the obsolete IBM 360/195 in the main data processing complex, COSMOS, by a modern machine more suited to the support of on-line interactive terminals. Significant progress was made in automating the acquisition of climatological data following the introduction of a new system of capturing outstation data received over telecommunication channels.

Automation of outstation functions

The second minicomputer-based OASYS became operational at the Principal Forecasting Office (PFO) at Headquarters, RAF Strike Command (HQSTC) in January. It has a similar design to that of the first which is now in its second year of operation at PFO London/Heathrow Airport, and comprises two PDP 11/60 processors, two large discs, four small discs, two pen-and-ink plotters, two electrostatic printer-plotters and the necessary communication interfaces and control terminals. Each OASYS is linked to the Meteorological Telecommunication Centre at Bracknell by a medium-speed line which is used to maintain an up-to-date store of observations which can be displayed in the form of plotted charts. Early in the year an additional facility was created to allow presentation of observations in text or pictorial forms on a graphics visual display unit. Plans are well advanced to give users access to forecast data by these methods.

A third OASYS was procured for London Weather Centre and installed initially at Bracknell to allow program development to proceed. It is planned to move it to the Centre in 1983 when work to convert the old forecast room into a computer room has been completed. Assistance was given to staff from the Directorate of Naval Oceanography and Meteorology in preparing a case for the purchase of an OASYS-like system to be installed at the Fleet Weather and Oceanographic Centre at Northwood.

Information can also be made available to main and subsidiary forecast offices more rapidly and in a form which can be assimilated more readily than at present, but it is necessary to test whether this can be achieved in a cost-effective manner. As a first step, equipment is being purchased for a pilot experiment to be conducted next year at two RAF stations, Honington and Lyneham. Each will have a Remote Outstation Automation System Terminal (ROAST) consisting of a simple visual display unit and a printer capable of producing text or graphics. The ROASTs will allow forecasters to extract the latest observations and forecast data from the HQSTC OASYS on demand. At present such information is broadcast in the form of bulletins and charts on teleprinter and analogue facsimile networks.

Replacement of IBM 360/195

A competitive procurement exercise resulted in an order being placed with IBM in July for the supply of a 3081 model D processor to replace the 360/195. The new machine was delivered in November. Although of somewhat similar processing power, it has eight times the main storage and at least four times the input/output capacity of the 360/195. The combination of modern hardware and software enables the 3081 to achieve a greater throughput of general-purpose computing tasks, in addition to those computationally intensive jobs which are not suited to the CYBER 205. Integration of the 3081 into the COSMOS computer system will be completed in 1983 with the delivery of additional disc storage units. As a result of advances in technology it will be possible to double the on-line capacity of the IBM parts of COSMOS by adding just four disc units, each of 2500 million bytes capacity.

Following the decision to acquire the 3081, user Branch requirements for terminal services were surveyed during the year in order to formulate plans for a modest expansion of the IBM terminal system in 1983. The intention is to give on-line access to the IBM system to support the work of programmers, managers, research scientists and staff who provide services based on the scientific and administrative archives of machinable data. With the combination of on-line terminals and 'user-friendly' software, it will be possible to improve the presentation of relevant information in a speedy and intelligible fashion to all these categories of staff.

Development of computer-based applications

With the installation in March of a proprietary data-base management system (IDMS) on COSMOS, it became possible to plan the phased introduction of a computer-based Management Accounting and Information System (MAIS). The objective is to introduce those components dealing with staff time, computer usage, major equipment purchases and long-term costings into operational use by the beginning of the 1983/84 financial year. This will enable the major cost elements of Meteorological Office activities to be monitored in a more effective and timely fashion than has been possible hitherto. In the first instance most data processing for MAIS will be carried out as batch work, regular reports being generated for management. Later, on-line access will be provided to give facilities for dealing with *ad hoc* queries and data entry.

Many classes of meteorological data are best displayed in pictorial formats. Examples abound, both in the forecast office—plotted charts, upper-air diagrams, satellite and radar images—and in research and services activities. A major application of computers has consequently been the automatic generation of graphical representations of weather data. The computer not only performs tasks faster and more accurately than a human draughtsman, but can do tasks which would be beyond the capability of any manual process; a good example is the 'stretching' of a satellite image to conform to a particular map projection. A computer graphics system capable of combining conventional data with images derived from satellite and radar observations is the only method whereby a forecaster could derive the maximum benefit from these diverse sources of information, and do it quickly enough for his output to be useful in real time. It is likely that the optimum system will be one in which human intelligence and judgement interact with a powerful data processor/ display system. A group drawn from research and services Branches has met during the year to study both the needs of the meteorologist and the technology which might provide a solution. It has been proposed that a research and development computer graphics system be established in order that further development of powerful interactive techniques may proceed.

For over two decades the Meteorological Office has pioneered the application of computers to major scientific endeavours which depend upon massive computational power. However, it has also acquired small computers to assist in specific information processing tasks. A good example is the National Meteorological Library's system for processing accessions. This continues to be supported. During the year a small microcomputer-based system was developed for use by the Marine Climatology Section at exhibitions. The system allows demonstration of its services, based on extensive archives and analytical capability, independently of central facilities. Approval to introduce some word processing facilities in the Office was obtained in the autumn.

Machinable archives

The generation of machinable data archives has continued. With the acquisition of the data base management system, IDMS, plans were made to increase the scope of the catalogue of available data and to make the catalogue easier to use and update. Partial automation of retrieval of data from the archives was started with the aid of proprietary software in conjunction with the catalogue. Major archives of climatological data, from a number of marine and land-based sources, have been under development for some time. During the year several of these were handed over to user Branches together with the software necessary to maintain them.

Investigation of means of capturing climatological data which do not require manual transcription to machinable form continued. The initial cost of keyboard-to-cassette systems is still too high to justify their use, at least in the short term. However, a trial of optical character recognition (OCR) equipment early in the year was sufficiently encouraging to warrant procurement of such equipment.

METEOROLOGICAL TELECOMMUNICATIONS

The Telecommunication Branch is responsible for the provision of telecommunication support to the whole of the Office, and for the operation of the Meteorological Telecommunication Centre (Met TC) at Bracknell. Rapid and reliable communications are vital to a wide range of activities in meteorology, and as the observing and forecasting capabilities expand so the demands placed on the communication facilities increase. Every effort is made to develop these facilities in a way which not only meets the changing user requirement but by taking advantage of modern developments in communications technology does so in the most efficient and cost-effective manner. In this context 1982 has been a year for consolidation and further development of the automated systems introduced in 1981 and for intensive planning of further major automation projects which will be implemented over the next two years or so.

The Met TC plays a key role in the exchange and dissemination of meteorological information both within the United Kingdom and internationally. Figure 6 shows the principal types of data handled, where they come from and where they are sent to.

The international exchange of data is effected largely via medium-speed circuits in the range 1200 to 9600 bits per second (bps) controlled by a Ferranti Argus 700S computer system which in 1982 provided a very high availability of service (over 99.7 per cent). Data are received from all parts of the world over the complex network of communication links known as the WMO Global Telecommunication System (GTS). As a Regional Telecommunication Hub (RTH) on the Main Trunk Circuit (MTC) of this network the Met TC has responsibility for maintaining the flow of traffic between Europe and North America and for the collection and injection onto the GTS of observations from the United Kingdom, Republic of Ireland, Greenland, Iceland and the Netherlands as well as from ships at sea, and aircraft operating over the eastern North Atlantic.

Bracknell continues to act as the Shore Collecting Centre for reports from the Ocean Weather Ships of the international North Atlantic Ocean Station (NAOS) network. However since May these reports have been received via the British Telecom Coast Radio Station, Portishead, using a Telex over Radio (TOR) semi-automatic method of communication rather than the manually operated Morse radio links direct to Bracknell which were used for many years. The new system is now operating satisfactorily and the consequent saving of staff aboard ship and at Bracknell has contributed much to the reduction of operating costs which was essential for the continuation of the NAOS scheme.

In addition to controlling circuits to centres overseas, the Ferranti Argus system controls distribution of data at 4800 bps to the OASYS minicomputer systems at the Principal Forecasting Offices at London/Heathrow Airport and Headquarters RAF Strike Command. Data from the GTS and processed information from the main COSMOS data processing system at Bracknell are supplied over these links. A dedicated Ferranti Argus 700G computer system provides link control functions for the 9600 bps link between COSMOS and the main Argus system, and for the 4800 bps link between Bracknell and the European Centre for Medium Range Weather Forecasts (ECMWF) at Shinfield Park. All available data for the whole globe are passed to ECMWF over this link and coded analyses and forecasts received over the link from the Centre are distributed daily on the GTS.

Within the United Kingdom the program for the installation of AUTOPREP microcomputer systems to assist the collection of observation reports has been continued and systems are in operation at all but one of the major Collecting Centres. These systems have been enhanced during the year by the addition of bulk memory thereby providing a faster response to operator commands and a marked improvement in reliability. The data entry facilities using visual display units, and automatic telex handling facilities provided on some of these systems, are proving to be of great assistance for the dissemination of forecasts, and other information, from the regional forecasting offices with which the

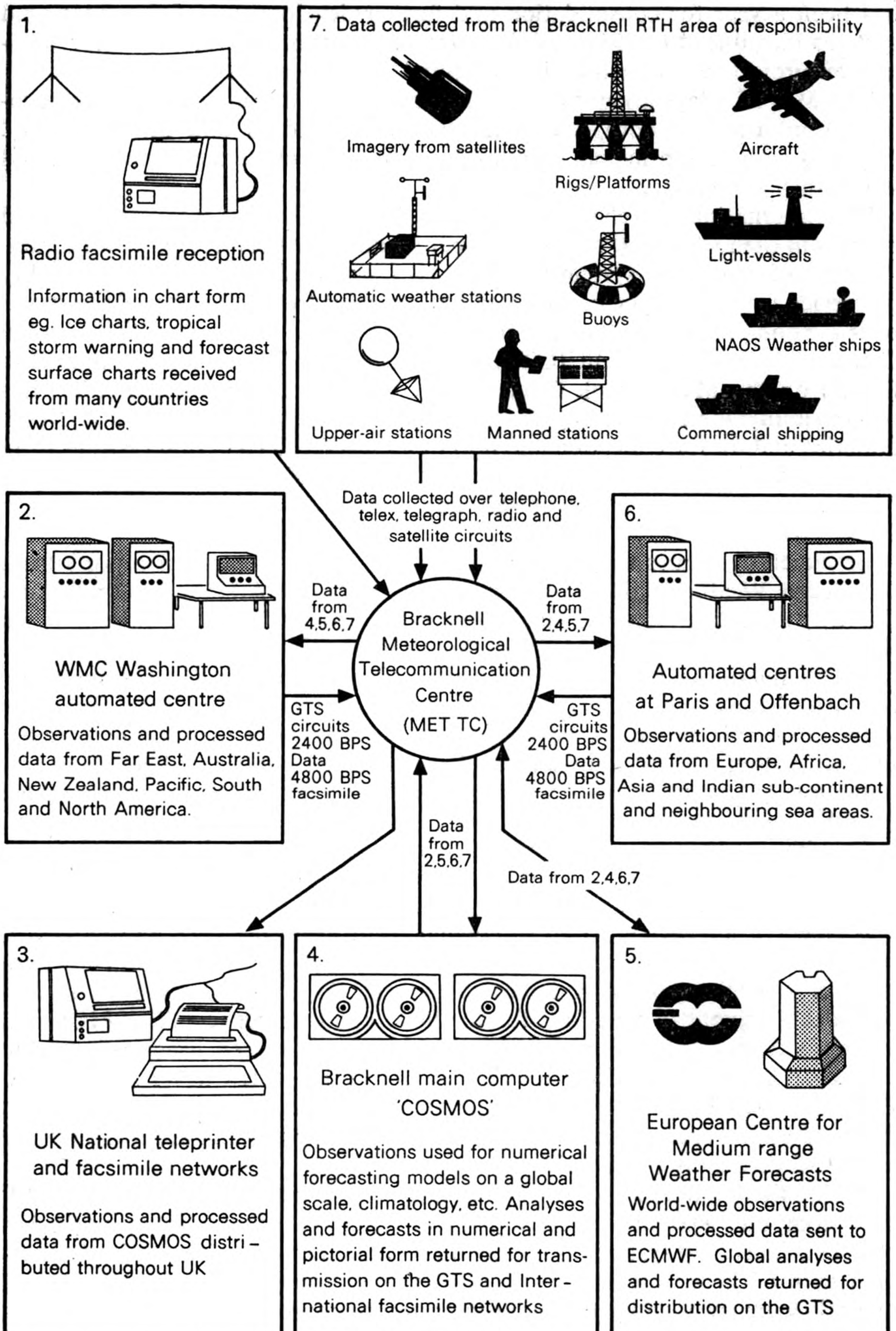


Figure 6—The principal types of data handled by Bracknell Meteorological Telecommunication Centre

Collecting Centres are associated. The 100 baud teleprinter broadcasts MCCA and MCCB introduced last year have provided a reliable and improved service for the distribution of alphanumeric data to offices throughout the United Kingdom.

The MOLFAX facsimile program of pictorial products was substantially changed towards the end of the year in order to include some of the products now available from the new numerical forecast model. These have been added to the regular transmissions of plotted charts, tephigrams, analyses and forecast charts prepared by the Central Forecasting Office.

Distribution by facsimile of Area Forecast System charts prepared at Bracknell and London/Heathrow Airport in support of civil aviation operations has continued. They are sent by landline to many European countries and the GFE radio-facsimile broadcast of these products has been maintained. The latter program also includes a range of products intended to meet the needs of ships at sea and other maritime interests. A second radio-facsimile broadcast, GFA, provides a range of analyses and forecast charts of more general meteorological interest.

Satellite imagery, received from the RAE satellite ground station at Lasham and processed by the computer-controlled AUTOSAT system, is supplied to the Central Forecasting Office at Bracknell, and to other United Kingdom stations over the SATFAX facsimile network. The main sources of the imagery during 1982 have been the NOAA-7 polar orbiting satellite and the European geostationary meteorological satellite Meteosat-2, though images have also been received from the United States geostationary satellite GOES-East. Distribution of the GOES-East images has been confined to a few of the larger forecasting offices. Some 30 stations are served by SATFAX at present and action to equip a further 13 stations is in hand. AUTOSAT software developments during the year have included the automatic addition of coastlines and latitude/longitude grids to the NOAA-7 images. This has saved time and effort previously expended in manual gridding at each user station.

Upgrading of international circuits

Good progress has been made during the year with the upgrading of certain international circuits for operation in accordance with CCITT recommendation V29 (CCITT being the international body responsible for the formulation of standards in communications). Using multiplexing techniques the V29 modems provide 2 channels at 2400 bps and one at 4800 bps on a single medium-speed circuit. The 4800 bps channel is being used for transmission of uncoded digital facsimile charts while the other channels are used for simultaneous transmission of data.

These procedures have been satisfactorily implemented on the circuits linking Bracknell to Offenbach, Washington, Paris and Reykjavik. In each case they represent a substantial increase in the capacity of the circuit as well as a great improvement on the former arrangement whereby digital data and analogue facsimile transmissions had to be carried alternately on a single channel. Further application of V29 procedures is planned.

Developments in automation in the Met TC

Plans are well advanced for the replacement of the ageing Marconi Myriad message-switching computer system at Bracknell. This system, which controls the many low-speed telegraph circuits operated through the Met TC, has been in operation since 1974. In addition to the fact that its facilities are now insufficient to meet all requirements, much of the hardware is obsolete and increasingly difficult to maintain. Following formulation and refinement of a very comprehensive User Requirement for the new system (to be known as AUTOCOM Phase IV), tenders were received from three short-listed contractors in the summer and a contract was placed in the autumn. Delivery of the system is due in 24 months from date of contract. It will be capable of controlling traffic on 64 low-speed (telegraph) lines and 8 medium-speed lines, and it is designed to operate in accordance with the latest international standards. Important features of the system will be the facilities for program development, the potential for further expansion and the provision of an easily-accessed data base. The latter will provide the opportunity to establish request/reply facilities for users at home and overseas.

Delivery of the first of two computer systems (Ferranti Argus 700GX) intended to control the growing program of digital facsimile transmissions took place at the end of the year. It will be used initially to take products in digital form from the COSMOS computer system and to convert them to analogue facsimile form for transmission over the MOLFAX network. In due course there will be a transition to fully automatic digital operation on all facsimile output from Bracknell. Full operational implementation of the system must await the delivery of the second, back-up, system in 1983.

A Ferranti 'Telex Manager' computer-based data preparation system has been installed in the Met TC to perform many tasks relating to teleprinter and telex operation that were previously done manually. The system can accommodate 24 telegraph lines, 8 of which can be from the public telex network. It offers a wide range of facilities to improve the speed and accuracy with which many kinds of messages can be compiled and transmitted, including visual display unit editing facilities and a multiple address facility.

International and Planning

For many years the successful application of meteorology has depended on effective international collaboration in making observations from a wide area rapidly available. With the introduction into operational service of numerical models covering the whole globe this co-operation, in both the collection and transmission of data and in many other aspects of application and research, is now even more important.

The focal point for co-operation in meteorology is the World Meteorological Organization (WMO), a specialized agency of the United Nations having a membership of 158 states or territories with a Headquarters in Geneva. The governing body of the WMO is the Congress, composed of the Permanent Representatives of Members, which meets every four years; it last met in 1979. Between Congresses the work of the Organization is supervised by an Executive Committee (EC) of 29 members of which the Director-General is one of 19 members elected to represent the International Meteorological Community rather than individual countries. The remaining members are the President and three Vice-Presidents of WMO and the six Presidents of Regional Associations. The EC meets annually and the 34th session took place between 7 and 24 June 1982. The Director-General was assisted at this meeting by the Assistant

Director (International and Planning) and Mr M. W. Stubbs. The EC reviewed the whole range of WMO activities but three matters dominated discussions at this Session. These were the Programme and Budget for the Quadrennium 1984–87, the development of a Long Term Plan embodying work programs for the period 1984–93 and the urgent need to develop further the World Weather Watch (WWW), a world-wide system for the collection, dissemination and processing of data.

Matters of interest in particular geographical areas within the WMO are co-ordinated by six Regional Associations. The UK is a member of two Regional Associations, Europe and Africa, both of which met during the year. Regional Association VI (Europe) met in Rome from 5 to 15 October 1982 when the UK was represented by the Director-General, assisted by the Deputy Director (Communications and Computing), the Assistant Director (Central Forecasting) and the Assistant Director (International and Planning). Regional Association I (Africa) met in Cairo from 15 to 25 November 1982 when the UK was represented for part of the Session by Mr M. W. Stubbs.

Scientific and technical matters are studied and co-ordinated in eight Technical Commissions, each of which specializes in a particular aspect of meteorology or hydrology. The Commission for Aeronautical Meteorology held a Conjoint Meeting with the International Civil Aviation Organization in Montreal from 14 April to 7 May 1982 during which the Deputy Director (Forecasting Services) was assisted for part of the Session by Mr K. Bryant and Mr R. G. Sowden. This meeting recommended a new Area Forecast System for civil aviation in which the UK would provide one of two World Area Forecast Centres. The Commission for Climatology and Applications of Meteorology (CCAM) met in Washington from 19 to 30 April 1982 when the UK was represented by the Assistant Director (Climatological Services).

Mr M. W. Stubbs also made liaison visits to Kenya, Mauritius, the Seychelles, Tanzania and Zambia where he discussed the operation of the WMO Voluntary Co-operation Programme within which the UK assists developing countries to develop their meteorological services for the benefit of the WWW. The UK contributes to the observational network in data-sparse areas by operating surface and upper-air observing stations on the remote South Atlantic Island of St Helena and on Tuvalu, Kiribati, and by assisting in the operation of other stations in the Seychelles and Vanuatu. For Vanuatu, negotiations towards obtaining an Agreement or Understanding to regulate the co-operation with that Government continue.

Meteorological aspects of other international activities are dealt with through such organizations as the International Civil Aviation Organization and the North Atlantic Treaty Organization (NATO). The International Council of Scientific Unions, in which scientists participate as individuals rather than as representatives of scientific bodies, is responsible together with WMO for the Global Atmospheric Research Programme of which the new World Climate Programme is an important part. During 1982 the final sub-Programme of the recent First GARP Global Experiment (FGGE), the Alpine Experiment (ALPEX), was completed. ALPEX was designed to secure a very detailed body of observational information on meteorological phenomena in the Alpine region.

British contributions to Antarctic Meteorology are the responsibility of the British Antarctic Survey (BAS) which maintains a program of surface and upper-air observations at its bases. The Meteorological Office supports the operations of BAS WWW stations by providing consumables and some equipment; the level of this support is reviewed from time to time in the light of changing circumstances. During the year discussions took place between the Meteorological Office and BAS on the level of support which should be provided during the coming five years. It was agreed that the Meteorological Office will assist BAS in re-equipping the upper-air station at Halley Bay (badly damaged by fire during 1981) and that subsequently it will concentrate its efforts on providing support for that station. Because of the nature of the Antarctic Treaty which governs activities in Antarctica, Antarctica does not constitute a WMO Region. However, essential co-ordination of arrangements for meteorological observations and communication is accomplished by a WMO EC Panel on Antarctic Meteorology of which Mr G. J. Day, Assistant Director (International and Planning) is Chairman. The Panel held a meeting between 5 and 8 April 1982, its first since 1969, at which a great deal of useful work was accomplished despite the rather unusual international circumstances of the time.

The United Kingdom also participates in two programs of 'European Co-operation on Science and Technology' (COST). COST Project 43 is concerned with the implementation, by concerted action, of a network of fixed data-gathering buoys in European waters and COST Project 72 is currently concerned with the development of international procedures, codes and communication protocols by which the data from radars measuring precipitation can be communicated across national boundaries and assembled nationally into useful composite displays. In this context, Dr D. N. Axford, Deputy Director (Observational Services) visited the Irish Meteorological Service in Dublin in June to discuss the possible combination of the Shannon Weather Radar with the semi-operational UK Weather Radar Network which now covers some of England and Wales. Negotiations were successful and a Letter of Agreement was exchanged between the two Services.

A new meteorological initiative during the year was the formation of a Consortium of Meteorological Services to develop for production an Aircraft to Satellite Data Retrieval System (ASDAR). ASDAR is a means to extract, from the data stored in the flight systems of wide-bodied civil aircraft, information on wind velocity, air temperature, position and height which can then be relayed via geostationary meteorological satellites to collecting stations within the WWW. A prototype system, developed in the USA, was used in the FGGE and found to have considerable potential as a component of the WWW. However, a commercial unit was not available and the Consortium was formed by the Meteorological Services of Australia, Canada, the Federal Republic of Germany, Holland, New Zealand, Saudi Arabia, the UK and the USA to arrange for the development of a unit suitable for production. The Chairman of the Programme Board of the Consortium, is Mr G. J. Day, who is Assistant Director (International and Planning).

The Consortium will arrange for further development of the system so that it will permit the acquisition of detailed profiles of wind velocity and temperature during the ascent and descent phases of flights by civil aircraft. This latter facility is expected to be a substantial contribution to the WWW in the lower levels of the atmosphere which are not well covered by the present sounding systems of operational meteorological satellites.

The Meteorological Office Programme Board, formerly the Programme Review Committee, which comprises the senior Directorate of the Office, kept under review the progress of the Meteorological Office Programmes and the direction and distribution of effort. The International and Planning Branch provided the Secretariat for the Programme Board which met during April and November. During the year, management information was assembled on a wide range of projects and activities in support of the Programme Board's functions, and information was supplied for use by individual project managers. Experience with this management information service provided a useful guide to the design of a computer-based management information system now under way in the Meteorological Office.

Appendix III (Page 156) lists the meetings of WMO and other meteorological bodies in which Meteorological Office staff participated, together with other visits abroad.

F. H. Bushby,
Director of Services

STATISTICS OF THE SERVICES DIRECTORATE

The quantative analyses in this section are intended to provide an indication of the distribution of work within the Directorate of Services and of the extent of the services provided.

TABLE I—NUMBER OF OFFICES OF VARIOUS TYPES STAFFED BY THE METEOROLOGICAL OFFICE AND OPERATING ON 31 DECEMBER 1982

	Within UK	Overseas
Principal Forecasting Offices associated with the RAF	1	—
Main Meteorological Offices associated with the RAF	5	2
Subsidiary offices associated with the RAF	31	4
Subsidiary offices associated with the Army	3	1
Subsidiary offices associated with MOD(PE)	3	—
Observing offices associated with the RAF	4	1
Observing offices associated with MOD(PE)	1	—
Principal Forecasting Offices associated with civil aviation	1	—
Main Meteorological Offices associated with civil aviation	3	—
Subsidiary offices associated with civil aviation	9	—
Observing offices associated with civil aviation	7	—
Upper-air observing offices	8	1
Weather Centres	8	—
CRDF offices	4	1
Port Meteorological Offices	7	—
Offices associated with the Agricultural Development and Advisory Service (MAFF)	5	—
Other offices	15*	—

*Three of these stations are administered by DR Met O

Notes

A Principal Forecasting Office meets the need of aircraft flying over long distances and operates throughout the 24 hours.

A Main Meteorological Office operates throughout the 24 hours for the benefit of aviation and normally supervises the work of subsidiary offices.

A subsidiary office is open for that part of the day necessary to meet aviation requirements.

At an observing office no forecaster is available.

An upper-air observing office may be located with an office of another type if this is convenient.

Weather Centres are located in certain large cities.

CRDF offices form the network for thunderstorm location.

Port Meteorological Offices are maintained at the bigger ports.

TABLE II—OCEAN WEATHER SHIPS

To meet the United Kingdom obligations under the WMO Agreement for the Joint Financing of the North Atlantic Ocean Stations (NAOS), the Office operated one ocean weather ship. This was employed to man Ocean Station 'L' (57°00'N, 20°00'W), one of the four stations of the network, together with the Netherlands ocean weather ship, each ship spending an average 30 and 26 days respectively on station each voyage. The station was manned for a total of 182.6 days by the UK ocean weather ship in 1982 and the ship was on passage for 32.3 days. Two ships from France one from Norway and five ships from the USSR served at the other three stations.

TABLE III—MERCHANT SHIPS AND SEA STATIONS

A total of about 7474 ships of the merchant navies of the world make and transmit meteorological reports to the appropriate meteorological centres ashore under arrangements co-ordinated by the World Meteorological Organization. Most of them, including British ships, do this on a voluntary basis. Ships which report in full at four specified times daily are known as 'selected ships'; those which report at the same times daily, but in a less complete form, are known as 'supplementary ships'. A number of coasting vessels, lightships, distant-water trawlers, 'auxiliary ships', platforms, rigs and buoys also make and transmit meteorological observations.

On 31 December 1982 the numbers of British ships reporting were:

Selected ships	412
Supplementary ships (including 1 trawler)	11
Coasting vessels	55
Lightships (including 1 light-tower)	13
Trawlers	—
Auxiliary ships	8
Total	499

The British Voluntary Observing Fleet includes ships of many shipping companies, and the numbers on the various routes are as follows:

UK to Australasia	19
UK to Far East	28
UK to Persian Gulf	16
UK to South Africa	20
UK to West Indies	10
UK to Atlantic coast of North America	41
UK to Pacific coast of North America	4
UK to South America	8
UK to European ports	93
UK to Falkland Islands and Antarctica	2
UK to distant-water fishing grounds	2
World-wide trading	180

During a typical five-day period in June the average daily number of reports from ships and sea stations received at the Regional Telecommunication Hub (RTH) at Bracknell were as follows:

	Reports 1981	Reports 1982
Direct reception from:		
British ships	190	179
Foreign ships	112	74
Rigs, platforms, buoys	83	86
Total	385	339

Total number of reports received by geographical location (direct to RTH Bracknell and via the Global Telecommunication System):

	1981	1982
Eastern North Atlantic	880	756
Western North Atlantic	330	580
Mediterranean	80	98
North Sea	247	279
Arctic Ocean	65	69
North Pacific	777	776
All other waters	495	532
Total	2874	3090

TABLE IV—CLASSIFICATION OF STATIONS SUPPLYING CLIMATOLOGICAL INFORMATION

For climatological purposes, data are obtained not only from official sources but also from very many stations which are not part of the Meteorological Office. This table shows the distribution on 31 December 1982 of stations which supply climatological information, classified under the following headings:

- Met O Synoptic — stations manned by professional meteorologists.
- Auxiliary Synoptic — stations manned by non-Meteorological Office staff whose observations are used primarily in weather forecasting.
- Climatological — stations run by individuals or organizations co-operating voluntarily with the Meteorological Office and fulfilling the minimum requirements of reporting extreme temperatures and rainfall.
- Agrometeorological — climatological stations at establishments primarily concerned with agriculture.
- Holiday Resorts — stations participating in a scheme whereby information is sent daily to the Meteorological Office for communication to the Press.

The areas and titles of the districts are those used in the *Monthly Weather Report.*

	Stations supplying Returns						Stations supplying Autographic Records		
	Met O Synoptic	*Auxiliary Synoptic*	*Climatological*	*Agrometeorological*	*Holiday Resorts*	*Rainfall**	*Sunshine*	*Rainfall*	*Wind*
Scotland, north	8	7	32	1	0	336	23	14	14
Scotland, east	6	3	43	11	2	463	33	22	14
Scotland, west	5	5	49	2	0	499	25	22	16
England, east and north-east	7	3	18	7	4	521	26	15	15
East Anglia	9	0	19	14	3	414	30	24	11
Midland Counties	6	2	34	17	0	996	44	40	16
England, south-east and central southern	10	4	24	18	12	759	53	28	23
England, south-west	8	8	27	6	11	586	41	19	13
England, north-west	6	1	13	1	2	526	17	24	13
Isle of Man	1	1	0	0	1	18	3	1	3
Wales, North	1	2	15	3	2	254	13	4	3
Wales, South	4	5	14	5	1	294	14	15	5
Channel Islands	2	0	1	0	2	17	5	1	2
Northern Ireland	2	6	46	8	0	278	29	49	10
Total	75	47	335	93	40	5961	356	278	158

*Includes stations in earlier columns.

TABLE V—HEIGHTS REACHED IN UPPER-AIR ASCENTS

The following table shows the number of upper-air ascents giving observations of (a) temperature, pressure and humidity and (b) wind, which have reached specified heights, and the height performance of the largest balloons.

	Number of observations	Percentage of all balloons reaching 100 mb (≈16 km)	50 mb (≈20 km)	30 mb (≈24 km)	10 mb (≈30 km)	Percentage of largest balloons reaching 10 mb (≈30 km)
(a) *Temperature, pressure and humidity:*						
Eight stations in the UK ..	5787	95.8	88.6	70.5	19.5	46.4
One station overseas	729	97.0	88.5	69.5	20.2	25.5
One Ocean Weather Ship ..	708	96.9	86.0	71.2	9.6	—
(b) *Wind:*						
Eight stations in the UK ..	11 593	97.0	83.2	47.4	9.4	45.8
One station overseas	1457	97.7	83.6	44.5	9.8	24.7
One Ocean Weather Ship ..	696	92.1	79.5	66.4	8.3	—

TABLE VI—THUNDERSTORM LOCATION

Number of thunderstorm positions reported by CRDF network in 1982 .. .. 23 023

TABLE VII—METEOROLOGICAL COMMUNICATION TRAFFIC

Almost all the national and international exchanges of meteorological observations which are used in the construction of synoptic charts and the production of forecasts are effected by coded messages. These coded messages usually comprise groups of five figures and although there are wide variations in message length there are on average about 500 characters per message. The messages are exchanged by radio and land-line. In addition there are exchanges, both national and international, of meteorological information in pictorial format. This information mainly comprises analyses and forecast charts derived from processing observational data. The transmission method is primarily analogue facsimile by either radio or land-line, though digital methods are now employed on the Global Telecommunication System multiplexed data links to Washington and Offenbach.

The following figures are taken from an analysis of the traffic (mainly coded messages and information in pictorial format) handled by the Meteorological Telecommunication Centre, Bracknell for one typical day (24 hours) in November 1982. For comparison, some corresponding figures are given for 1981.

	Number of messages/products in one day In	Out	Total	Total in 1981
Coded messages:				
Land-line teleprinter and data transmission ..	18 750	121 450	140 200	102 658
Radio transmission	289	3030	3319	3748
Facsimile products (pictorial format):				
Land-line transmission	278	1060	1338	1302
Radio transmission	44	119	163	158

Notes

The increase in the total for land-line teleprinter and data transmission messages is mainly due to the introduction of medium-speed links with Iceland and with the OASYS mini-computer system at RAF HQ Strike Command.

The reduction in the total for radio transmission of coded messages reflects the fact that messages from vessels manning the North Atlantic Ocean Stations now arrive at Bracknell on a telex link.

TABLE VIII—SPECIAL SEASONAL FORECASTS

There is a need for forecasts of a special type at certain seasons. These are described in *Met O Leaflet* No. 1. The numbers receiving such specialized services are as follows:

	Year	Number of customers	Year	Number of customers
Consultancy services to farmers and growers	1981	184	1982	212
Weekend temperature forecasts (a winter service primarily for industrialists)	1981/82	74	1982/83	86
Winter road-danger warnings (primarily for local authorities) ..	1981/82	274	1982/83	300
Consultancy or forecast services ..	1981/82	46	1982/83	129

TABLE IX—FORECASTS FOR AVIATION

Forecasting for aviation constitutes the primary function of many of the offices. The Central Forecasting Office at Bracknell, acting as a Regional Meteorological Centre for the World Weather Watch, is mainly concerned with the analysis of the weather situation and with the issue of forecast charts for the guidance of other offices, including the two Principal Forecasting Offices which serve civil aviation from London/Heathrow Airport and military aviation from the Headquarters of RAF Strike Command. The Central Forecasting Office also has a commitment to civil aviation in the provision of wind and temperature charts for use with the significant weather charts produced by the Principal Forecasting Office at Heathrow and for the transmission of grid-point data direct to the British Airways BOADICEA and APOLLO computers at Heathrow and Prestwick respectively and to the Dutch and Belgian Meteorological Services.

The following figures indicate the numbers of forecasts issued for aviation and the numbers of meteorological briefings that took place during 1981 and 1982. These do not include warnings and routine general forecasts.

	1981	1982
Number of meteorological briefings for		
aviation in the UK	382 325	363 354
aviation at overseas stations	33 852	35 358
Number of aviation forecasts issued for		
aviation in the UK	1 773 885	1 790 458
aviation at overseas stations	151 549	155 337

TABLE X—NON-AVIATION ENQUIRIES

Non-aviation enquiries are handled by eight Weather Centres, in London, Manchester, Glasgow, Southampton, Newcastle, Nottingham, Bristol and Cardiff and the forecast unit at Lerwick Observatory. The function of these offices is to meet the needs of the general public for forecasts for special purposes. Many other forecast offices, established primarily to meet the needs of aviation, also answer requests for forecasts and other weather information from the general public, Press, public corporations, commercial firms, etc. These enquiries, most of which refer to current or future weather, are listed below according to the purpose of the enquiry. Recorded answering systems, other than Weatherline, are gradually being withdrawn. Enquiries to these systems are therefore not included in the figures shown below.

	1981	1982
Total number of non-aviation inquiries	2 029 685	1 838 079
Percentage relating to:		
agriculture	14.4	14.3
building	4.0	4.3
commerce, industry	4.4	5.6
holidays	16.2	15.5
marine matters	10.3	10.8
Press	12.3	13.9
public utilities	9.7	10.7
road transport	7.8	5.2
other known purposes	7.9	8.4
unknown purposes	13.0	11.3

TABLE XI—FLASH WEATHER MESSAGES

FLASH weather messages are passed to the BBC and to most independent broadcasting companies for inclusion in their programs at a convenient break. They are, effectively, warnings of the actual occurrence of weather conditions which might cause considerable inconvenience to a large number of people. The following table shows the kind of weather and areas for which FLASH messages are broadcast and the number issued in 1982.

Area	Dense fog	Moderate or heavy snow	Heavy rain	Glazed frost and icy roads	Severe inland gales	Blizzard	Strong winds
Edinburgh and south-east Scotland	—	1	—	—	1	—	—
Glasgow and south-west Scotland	—	—	1	—	—	—	—
Belfast and Northern Ireland	—	—	1	—	2	—	1
Industrial north-east England	—	—	1	—	6	1	2
Industrial Lancashire and Merseyside	—	—	3	—	2	—	—
Industrial Midlands	—	1	2	—	—	—	—
Bristol and Bath	—	1	—	—	1	—	—
South Wales	—	1	3	1	3	1	1
London and south-east England	—	—	2	—	1	—	—
Plymouth and south-west England	—	—	2	1	—	—	—
Yorkshire	—	—	—	—	3	—	—
Southampton and Portsmouth	—	—	—	—	—	—	—
Warnings covering more than one area or blizzards outside industrial areas	1	1	5	—	8	3	2
Totals	1	5	20	2	27	5	6

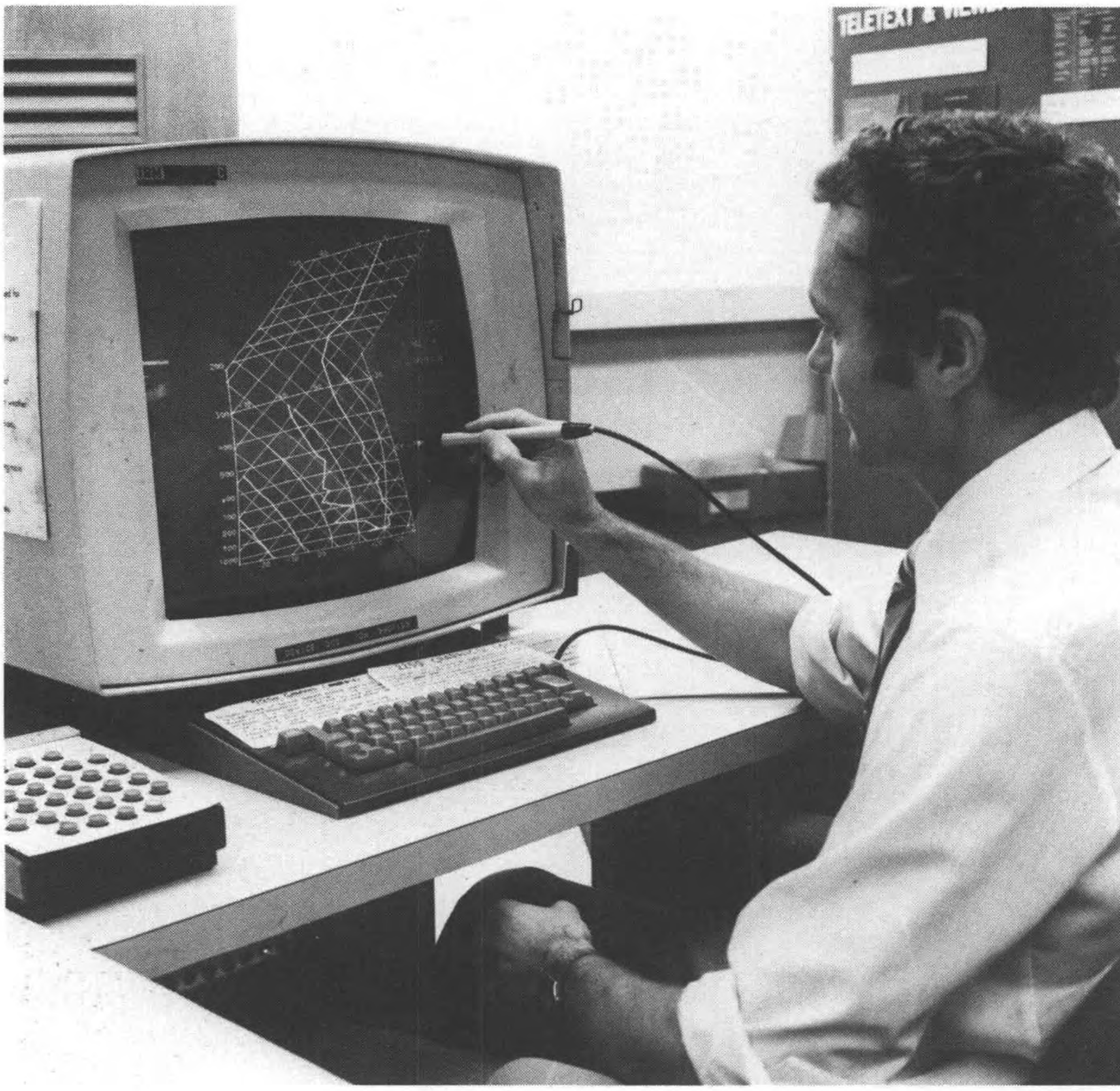
TABLE XII—'WEATHERLINE' FORECASTS

Information Service Centre	Forecast area	Number of calls 1981	1982
Aberdeen	Aberdeen and Grampian	0	57 200
Bangor, N.I.	Northern Ireland	9 846	17 366
Bedford	Herts, Beds and inland Essex	417 216	294 295
Belfast	Northern Ireland	475 529	380 546
Birmingham	Birmingham and Warwickshire	1 334 461	1 172 966
Bishops Stortford	Herts, Beds and inland Essex	134 689	123 252
Blackburn	North-west England	466 963	348 984
Blackpool	North-west England	263 378	211 762
Bournemouth	Dorset and Hampshire coast and Isle of Wight	497 569	496 308
Bradford	West Yorkshire	245 529	190 093
Brighton	Sussex and South Kent coast	936 322	763 417
Bristol	Somerset and Avon	926 397	776 799
Cambridge	Herts, Beds and inland Essex	120 040	220 855*
Cardiff	Glamorgan and Gwent	899 350	760 848
Canterbury	North Kent and Essex coasts	573 197	397 663†
Chelmsford	North Kent and Essex coasts	248 821	169 177
Cheltenham	South-west Midlands	198 236	174 814
Chester	Anglesey and North Wales coast	183 646	161 314
Colchester	North Kent and Essex coasts	355 552	333 366
Colwyn Bay	Anglesey and North Wales coast	129 757	130 572
Coventry	Birmingham and Warwickshire	371 901	272 064
Derby	East Midlands	333 221	203 775
Doncaster	South Yorkshire and Peak District	96 163	78 560
Dundee	Dundee, Fife and Tayside	0	63 472
Edinburgh	Edinburgh and Lothian	418 624	371 015
Exeter	Devon and Cornwall	498 925	480 853
Glasgow	Glasgow and district	856 608	811 071
Gloucester	South-west Midlands	345 760	259 230
Grimsby	Lincolnshire and Humberside	129 590	94 561
Guildford	London	250 453	214 751
Hastings	Sussex and south Kent coast	181 189	162 926
Hereford	South-west Midlands	167 635	136 239
High Wycombe	Oxfordshire, Buckinghamshire and Berkshire	235 749	240 307
Huddersfield	West Yorkshire	153 371	112 268
Ipswich	East Anglia	429 785	300 718
Leeds	West Yorkshire	599 736	452 643
Leicester	East Midlands	451 205	349 073
Lincoln	Lincolnshire and Humberside	276 686	231 801
Liverpool	North-west England	430 187	355 064
Liverpool	Anglesey and North Wales coast	53 713	48 433
London	London	4 910 633	3 915 905
London	North Kent and Essex coast	378 789	252 411
London	Sussex and South Kent coast	439 841	311 000
London	Oxfordshire, Buckinghamshire and Berkshire	329 063	272 171
London	Herts, Beds and inland Essex	201 709	140 660
London	North Downs and Weald	0	5 202
Lowestoft	East Anglia	52 890	52 499
Luton	Herts, Beds and inland Essex	393 567	328 927
Manchester	North-west England	912 370	789 745
Manchester	Anglesey and North Wales coast	95 602	72 415
Medway	North Kent and Essex coast	282 678	293 480
Middlesbrough	North-east England	289 094	260 586
Milton Keynes	Herts, Beds and inland Essex	90 598	73 836
Newcastle	North-east England	674 197	559 178
Newport, Gwent	Glamorgan and Gwent	171 145	156 175
Northampton	East Midlands	130 273	138 386

PLATE I

The Central Forecasting Office—the Senior Forecaster at work

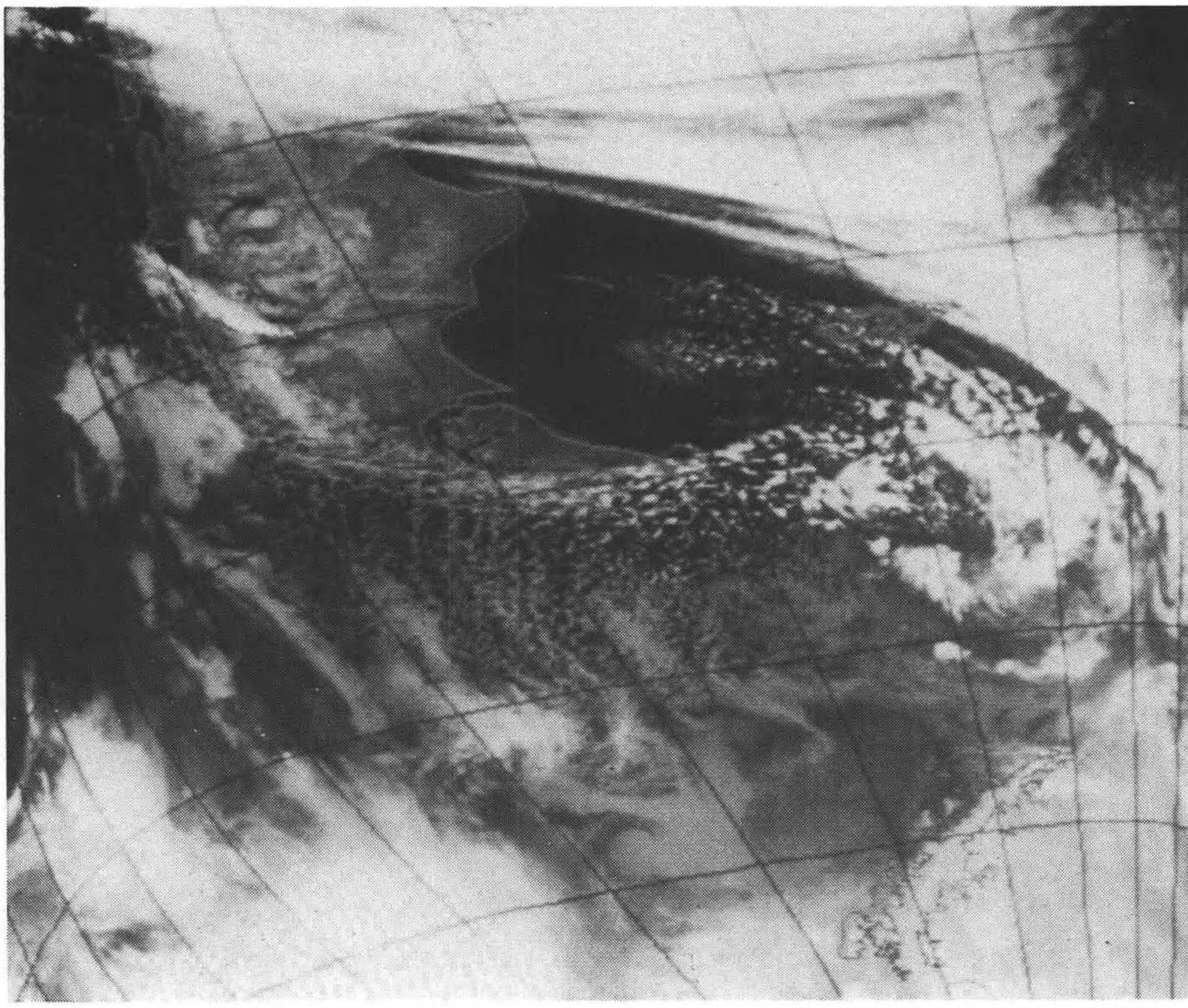
PLATE II



One of the visual display units in the Central Forecasting Office. The forecaster is displaying the temperature and humidity profile from Crawley's radiosonde ascent.

The satellite picture display system in CFO, which enables a sequence of pictures to be shown as a 'movie'.

PLATE IV



Satellite picture from NOAA 7 showing the cloud pattern over the South Atlantic shortly after 0600 GMT on 25 July 1982

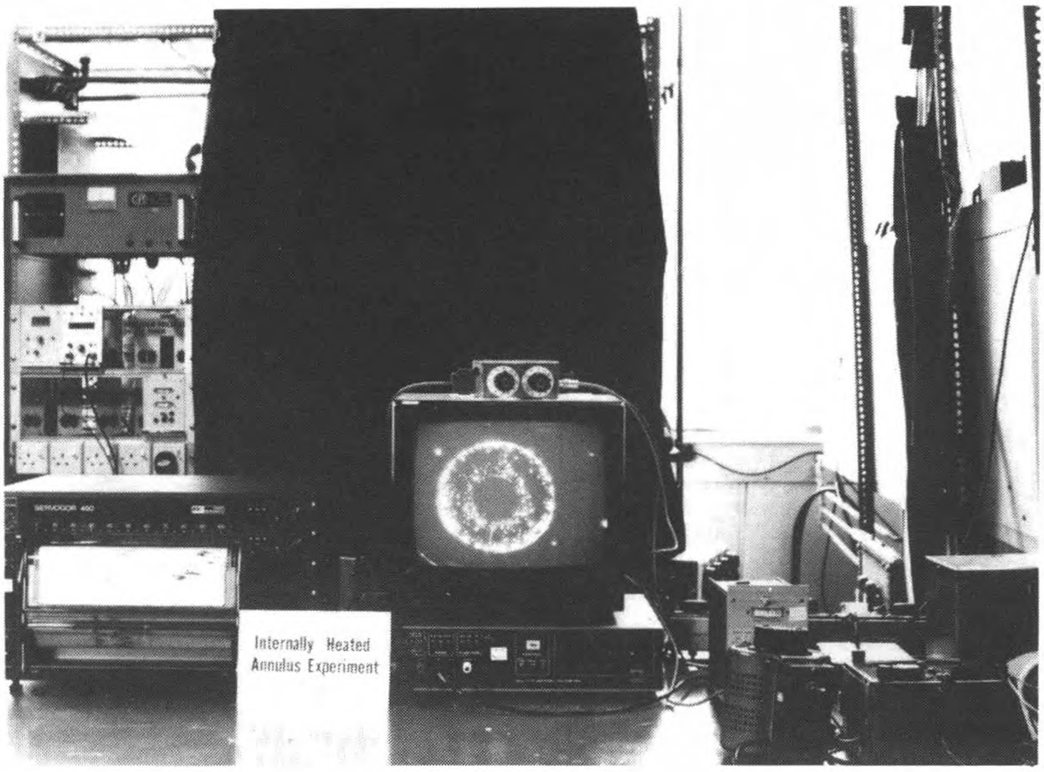
A depression to the south of the Falkland Islands was filling. The associated cold front had just cleared the islands and broken cloud gave rain and snow showers. Daytime temperatures barely reached 0°C and were accompanied by a fresh south-westerly wind.

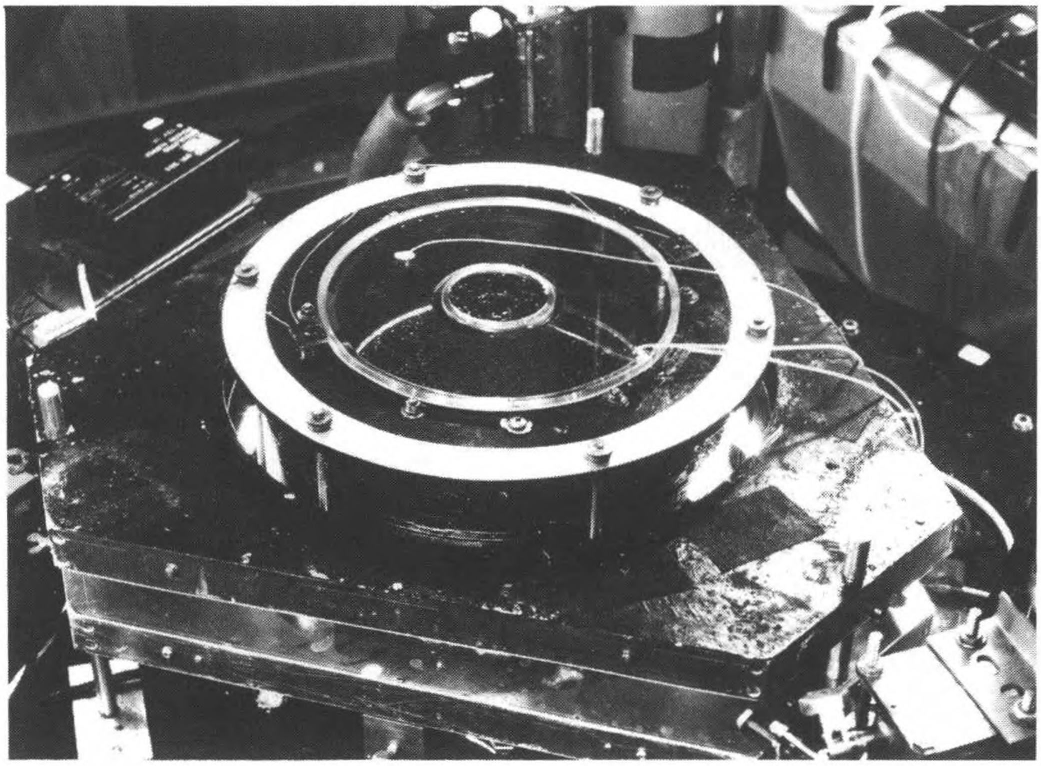
PLATE V

New premises of Belfast Weather Office at Progressive House, College Square East

PLATE VI

Ocean Weather Ship *Starella* (see page 47)





Geophysical Fluid Dynamics Laboratory

The upper picture shows the turntable and instrumentation used in a laboratory experiment on the effects of internal heating on rotating flow. The convection chamber is surrounded by black curtains to exclude unwanted light. The television monitor shows the positions of tracer particles which are used to determine the motion of the fluid. Temperatures at various points in the fluid are plotted on the chart recorder.

The lower picture shows the convection chamber. The working fluid occupies the annular region beneath the circular plastic lid. The entire apparatus is mounted on a turntable.

South Atlantic Medal presentation and congratulation on Honours—Monday 18 October 1982 (see page 139)
Left to right: Mr. J. Turner, M.B.E. (Met O 2), Mr R. S. Bell (Met O 2), Sqn. Ldr. W. R. McQueen, M.B.E. (Coningsby), FO S. W. Galaud (Met O 1), Flt. Lt. P. W. Davies (Met O 1), Flt. Lt. B. Phillips (London Weather Centre), Sir John Mason (Director-General), FO R. C. Adam (Kirkwall), Sqn. Ldr. H. Pettit (Benson), Gp/Capt M. Burton (DD Ops(Nav) RAF), Mr E. E. Williams (Met O 6), Sqn. Ldr. K. J. Maidment (HQSTC)

Information Service Centre	Forecast Area	Number of calls 1981	1982
Norwich	Norfolk and Suffolk	562 686	424 137
Nottingham	East Midlands	658 406	543 099
Oxford	Oxfordshire, Buckinghamshire and Berkshire	419 524	404 446
Peterborough	Herts, Beds and inland Essex	199 538	128 769
Plymouth	Devon and Cornwall	634 381	722 466
Portsmouth	Dorset and Hampshire coast and Isle of Wight	616 522	555 666
Reading	Oxfordshire, Buckinghamshire and Berkshire	538 483	706 364
Sheffield	South Yorkshire and Peak District	587 041	508 303
Southampton	Dorset and Hampshire coast and Isle of Wight	1 103 946	782 434
Southend	North Kent and Essex coasts	385 106	289 287
Southport	North-west England	81 225	61 972
Swindon	Avon and Somerset	88 973	69 308
Torquay	Devon and Cornwall	203 955	139 680
Tunbridge Wells	London	181 722	132 060
Total		30 310 956	25 510 988

*Also includes forecasts for East Anglia
†Also includes forecasts for Sussex and South Kent coast

TABLE XIII—CLIMATOLOGICAL ENQUIRIES

Met O 3, Met O 8, Edinburgh and Belfast receive a number of enquiries relating to past weather, to climatology and to the application of meteorological data to agriculture. The following figures give the total number of enquiries and the percentages of this number in various categories.

	1981	1982
Total number of climatological enquiries	37 936	44 540
Percentages relating to:		
agriculture (farming, forestry, market gardening)		25.6
building and design (including siting)		15.7
commerce (sales, marketing, advertising)		7.6
drainage		1.3
education and literature		3.9
flooding		0.2
heating and ventilation		4.2
industrial and manufacturing activities		1.9
law (damage, accident, insurance)		12.3
medical and health		0.4
Press and information centres		1.8
research		6.1
sports, hobbies, holidays		0.8
transport and communications		1.0
water supplies		3.6
miscellaneous (purpose known)		7.3
miscellaneous (purpose unknown)		6.3

TABLE XIV—DATA PROCESSING

	1981	1982
Computer installations:		
Number of tasks run on the 360/195 computer	269 000	240 000
Number of tasks run on the 3081 computer	—	52 000
Number of tasks run on the 370/158 computer	221 000	199 000
Number of tasks run on the CYBER 205 computer	18 000	92 000
Number of tasks run using the terminal system	58 000	59 000
Processor-controlled keying systems:		
Number of characters keyed at Bracknell	76 600 000	60 300 000
Number of characters keyed at Devizes	309 000	8 500 000
Punched-card installation:		
Number of computer cards punched	350 000	204 000

TABLE XV—INSTRUMENT TESTING, CALIBRATION AND ACCEPTANCE

	Tests	Calibrations
General meteorological instruments:		
Wind measuring	1115	555
Pressure measuring	1148	987
Humidity measuring	288	1
Precipitation measuring	289	14
Radiation measuring	298	298
Sunshine recording	28	—
Temperature measuring	3209	260
Balloons	14 080	—
Miscellaneous	6191	—
Electrical/electronic instruments:		
Instruments and systems	886	—
Instrument calibrations	—	255
Components	27 386	—
Radiosonde instruments:		
Components accepted	39 500	—
Humidity elements skinned and seasoned	5350	—
Pressure elements	42	6500
Reference elements	—	2200
Temperature elements	500	1020
Balloons	21 406	—
Radar reflectors	23 160	—
Parachutes	23 500	—
String unwinders	206	—
Recovered radiosonde transmitters	1997	—

DIRECTORATE OF RESEARCH

SPECIAL TOPIC—CARBON DIOXIDE AND CLIMATE

Introduction

Over the past decade there has been an increasing interest in the possibility that man may be altering climate on a global scale. Over the last 25 years, the amount of carbon dioxide in the atmosphere has increased steadily (see Figure 7). This increase is attributed to the burning of carboniferous fuel (coal, gas, oil) which releases carbon dioxide (CO_2) into the atmosphere directly. In fact, only about half the CO_2 released in the burning of fossil fuel appears to have remained in the atmosphere; the remainder is believed to have been absorbed by the ocean.

Attempts to forecast the changes in concentration of atmospheric CO_2 over the next 100 years or so have been made by first estimating the world's energy requirements over the next century, and then postulating what fraction will be produced by burning fossil fuels; the resulting concentration of atmospheric CO_2 has usually been estimated by assuming that a fixed fraction remains airborne. However, as living organisms both absorb and release CO_2 this may be too simple an approach and alternatively, one can attempt to predict the uptake of carbon dioxide by the oceans and the biosphere in detail. As there is much uncertainty in both the projected use of fossil fuels, and the partition of the resulting CO_2 between the atmosphere and the rest of the carbon cycle, it is not surprising that there is a wide range of concentrations predicted for future atmospheric CO_2. A typical forecast is that CO_2 will reach 600 parts per million (by volume) in the next 70 or 80 years, or about a doubling of the estimated pre-industrial level.

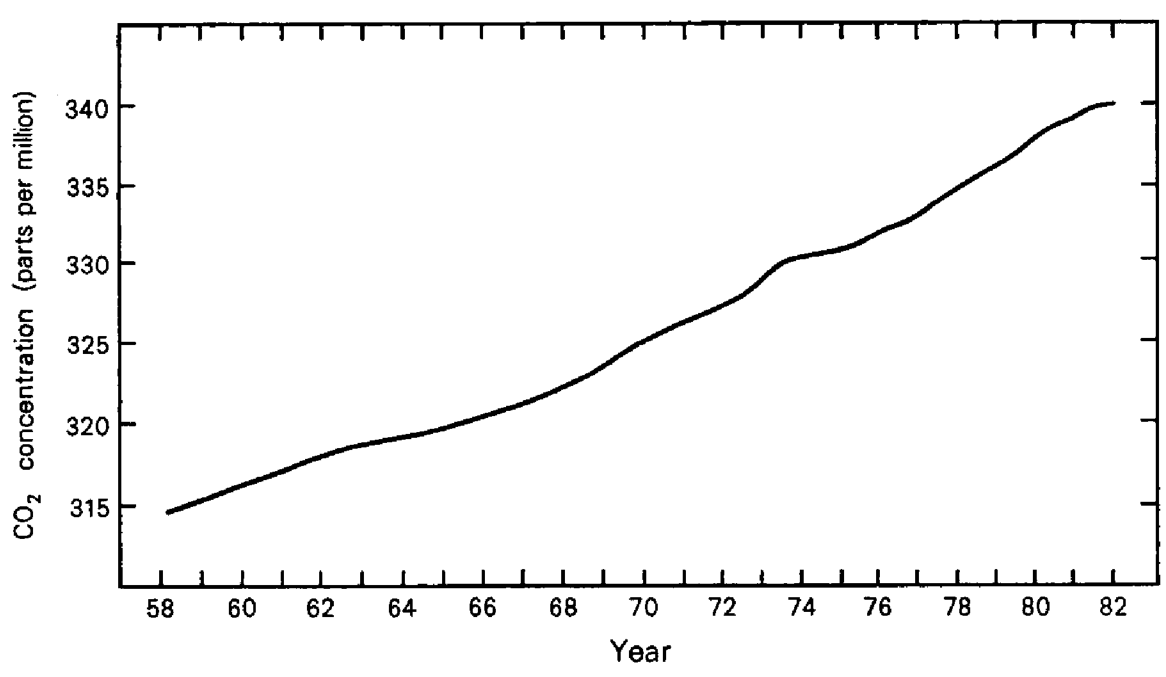


Figure 7—Changes in concentration of atmospheric CO_2 (parts per million) at Mauna Loa, Hawaii, 1958–82 (from Keeling 1982)

In 1938, Callendar suggested that the CO_2 produced by man could lead to changes on climate. It is known that raising CO_2 concentrations warms the lower atmosphere and the earth's surface directly. Recently, there has been much speculation that the initial warming could be amplified by various mechanisms to give changes in global patterns of temperature, precipitation and winds. This has led to suggestions that the main regions of grain production would become short of water, and that the predicted rise in polar temperatures would be sufficient to cause the rapid disintegration of the vast grounded west Antarctic ice sheet. This would raise the sea level by about 5 metres, with disastrous consequences for low-lying areas, including many of the world's major cities. While some of these conjectures are probably exaggerated, there is an increasing amount of evidence that changes due to increasing CO_2 will be significant.

The concentration of atmospheric CO_2 has risen by 8 per cent since 1957, and it may therefore be asked whether it is already possible to detect a rise in global mean surface temperature. As the expected warming is only about three-tenths of a degree Kelvin and this occurs within much larger variations due to other causes (see Figure 8) any CO_2 signal cannot be identified with confidence. Some of the variability is inherent in the atmosphere; some may be associated directly with some physical cause such as the increase in stratospheric dust following volcanic eruptions, or changes in the intensity of the sun. (See the 1976 *Annual Report* for a detailed discussion of climate variability).

Simplified heat balance of the earth–atmosphere system

Before discussing the physical processes relevant to a study of CO_2 and climate it is helpful to consider the earth's heat balance. All objects radiate heat. Generally, the intensity of radiated heat increases and the wavelength of radiation decreases as the temperature of the body increases. The sun, with a surface temperature of about 6000 K, radiates heat at ultraviolet and visible wavelengths up to about 4 μm (4×10^{-4} cm). Some of this incoming short-wave radiation is absorbed by the atmosphere, and some is reflected by clouds and the surface. The remainder is absorbed by the surface and is transferred directly to the atmosphere by conduction, indirectly by the release of latent heat following condensation of moisture which has been evaporated from the surface, or is radiated upwards to space. The earth radiates energy to space at longer infra-red wavelengths (4 μm upwards). The temperature of the earth and atmosphere is such that the outgoing long-wave radiation at the top of the atmosphere just balances the net incoming radiation from the sun. Clouds, ozone, CO_2, water vapour and other atmospheric trace gases absorb and emit long-wave radiation over specific wave bands. They absorb or 'trap' much of the long-wave radiation from the earth's surface, and re-emit it to space. The intensity of emission again increases with temperature. Because the atmospheric temperature is lower than that of the surface, the rate at which the earth–atmosphere system radiates to space is reduced, and the system can maintain a higher temperature. This is popularly known as the 'greenhouse' effect, and is responsible for our planet being some 20 °C warmer than the radiative equilibrium temperature of −5 °C which would occur without an atmosphere (assuming the reflectivity of the surface remained at about 0.15). A schematic representation of this earth–atmosphere system is given in Figure 9.

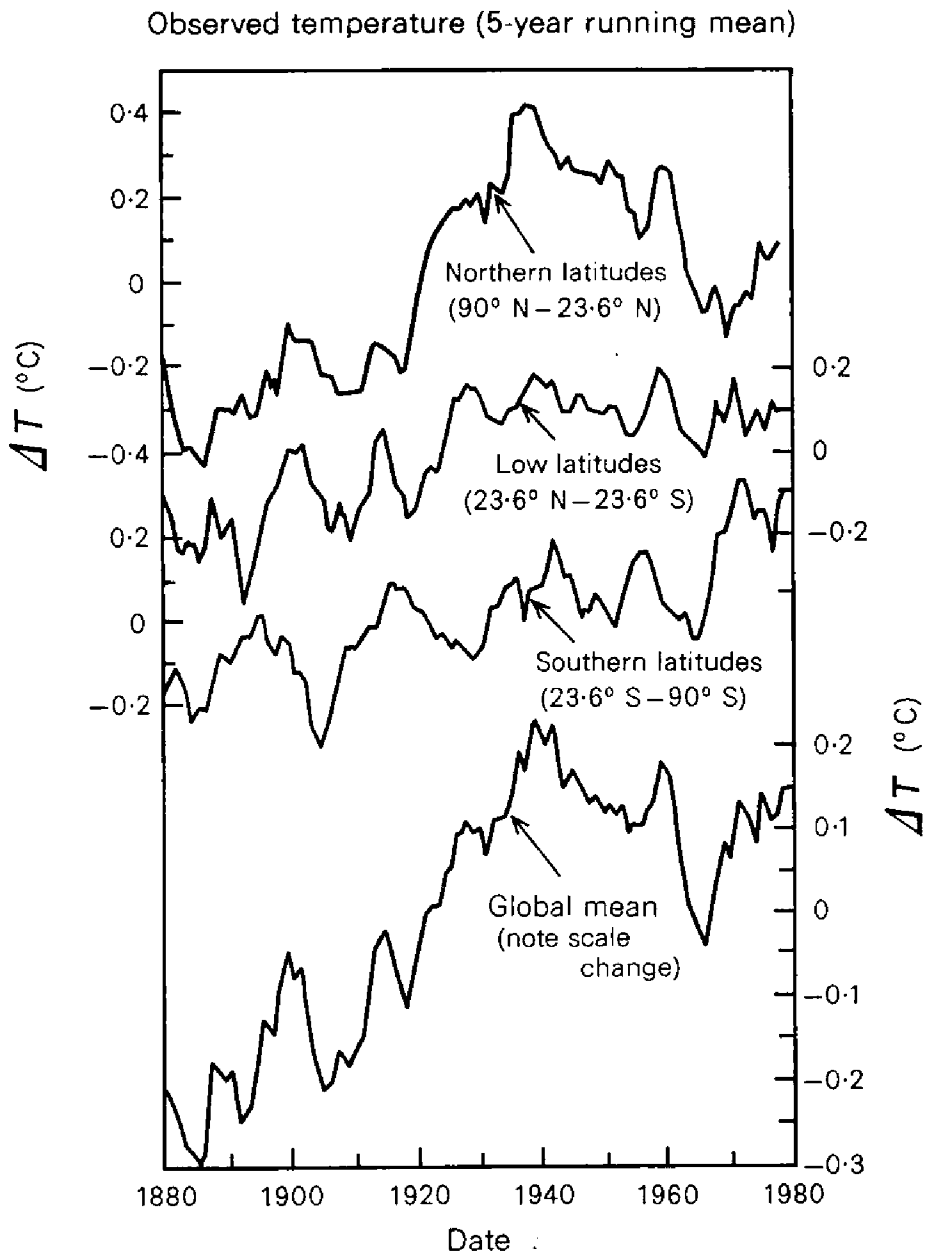


Figure 8—Changes in surface air temperature, 1880–1980 (from Hansen *et al.* 1981. Copyright 1981 by the American Association for the Advancement of Science)

It is worth considering the flux of radiation at the surface in more detail. Figure 10 shows the spectral distribution of infra-red radiation at the surface calculated using a typical mid-latitude summer profile of temperature and humidity. The solid line denotes the upward radiation from the surface, amounting to 424 W m^{-2}. The dashed line denotes the downward flux of radiation from the atmosphere received at the surface, amounting to 350 W m^{-2}.

In the region of 15 µm, where CO_2 absorbs strongly, the two curves are almost coincident, indicating that nearly all the energy emitted by the surface at those wavelengths is absorbed and re-emitted by the atmosphere. In the region 8 to 12 µm, known as the atmospheric window, very little energy is absorbed by the atmosphere, and most of the radiation from the surface is lost to space.

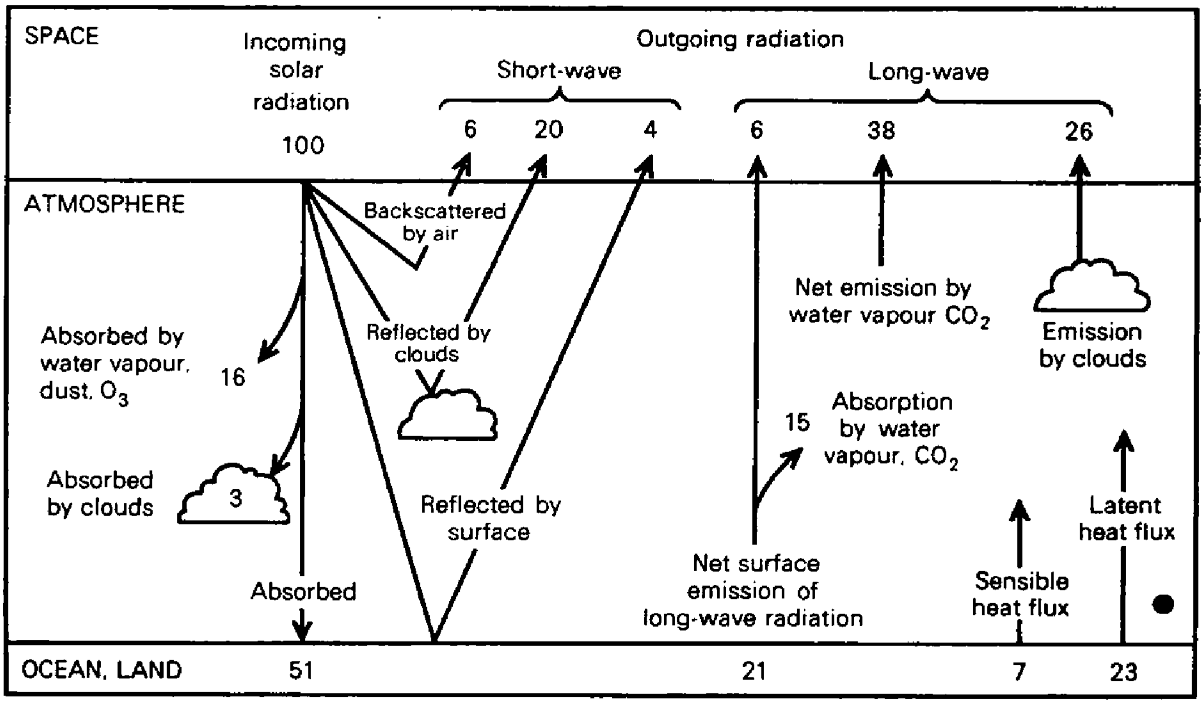


Figure 9—Heat balance of the atmosphere (from US National Academy of Sciences 1975)

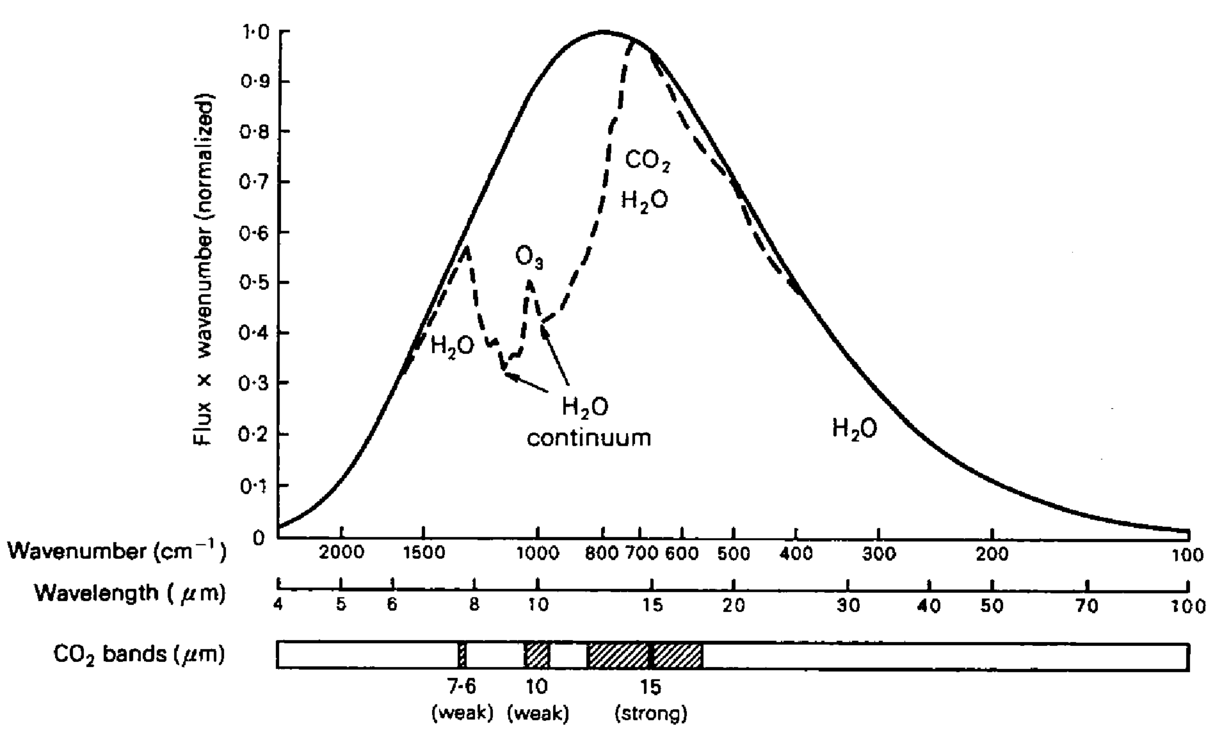


Figure 10—Spectral distribution of long-wave radiation from a mid-latitude summer profile of temperature and gaseous absorbers (Adapted from Roach and Slingo 1979)

The ordinate is flux × wavenumber (normalized to the maximum value), so that equal areas under the graph represent equal amounts of energy.

An increase in atmospheric CO_2 enhances both the emission and absorption of long-wave radiation at specific wavelengths. The net effect is that cooling to space is reduced, and the temperature of the earth's surface and of the atmosphere rise to restore the balance between the incoming and outgoing radiation.

Radiative–convective models

Simple models of the atmosphere consisting of a single vertical column, with a specified profile of temperature, moisture, CO_2, and ozone have been used to study the sensitivity of the heat balance of the earth's atmosphere system to CO_2 changes. The changes in heating rate can be calculated using a model of radiative transfer on profiles with normal and (say) doubled CO_2. If the CO_2 concentration is doubled in a typical mid-latitude summer profile of temperature and humidity, the downward long-wave flux at the surface increases by 1–2 W m^{-2}. This is small compared with the surface downward flux of 350 W m^{-2} in the original profile, as most of the energy at the relevant wavelengths has already been absorbed by the initial CO_2 and water vapour. There is also a reduction of 4–5 W m^{-2} in the cooling of the troposphere. If the atmospheric temperatures are allowed to adjust to this change in cooling, the surface receives a further 2–3 W m^{-2} from the warmer troposphere.

As indicated in Figure 9, the atmosphere is not in radiative equilibrium, but is heated by fluxes of sensible and latent heat from the surface, and cooled by radiation. This may be incorporated in the radiative model by transferring the heat from the surface to successive layers in the atmosphere, with the constraint that the fall of temperature with height, or lapse rate, does not exceed a given value. Such a radiative convective model can be run until the temperature profile reaches equilibrium, provided the solar angle, clouds, water vapour, CO_2, surface albedo and other parameters are specified. The temperature change found on doubling CO_2 will depend on the choice of these parameters. This sensitivity has been investigated in the Meteorological Office (Rowntree and Walker 1978).

Many studies made with one-dimensional models assume a constant lapse rate, often taking 6.5 K/km as a typical observed value. In this case the increase in temperature following a doubling of CO_2 will be evenly distributed over the lower atmosphere and surface, as shown schematically in Figure 11 (a). On the other hand, in moist convection the temperature in the lower layers falls off less quickly with height, especially in the lower troposphere. This is because a rising parcel of moist air cools adiabatically until it becomes supersaturated. The excess moisture condenses, and releases latent heat, which offsets the cooling. The warming due to increasing CO_2 will then be larger at the top of the troposphere than at the surface, (see Figure 11 (b)). This is illustrated more clearly in Figure 11 (c) which shows the distribution of temperature changes with height following the doubling of CO_2 in a radiative-convective equilibrium model with (1) a fixed lapse rate (6.5 K/km), and (2) a penetrative convection scheme which adjusts the lapse rate to allow for the release of latent heat. The changes in surface temperature are 1.29 K and 0.78 K respectively (Table 1).

The rise in temperature which accompanies the build up of CO_2 concentrations increases the capacity of the atmosphere to hold water vapour. Since moisture is readily available over most of the globe, and an increase in surface heating

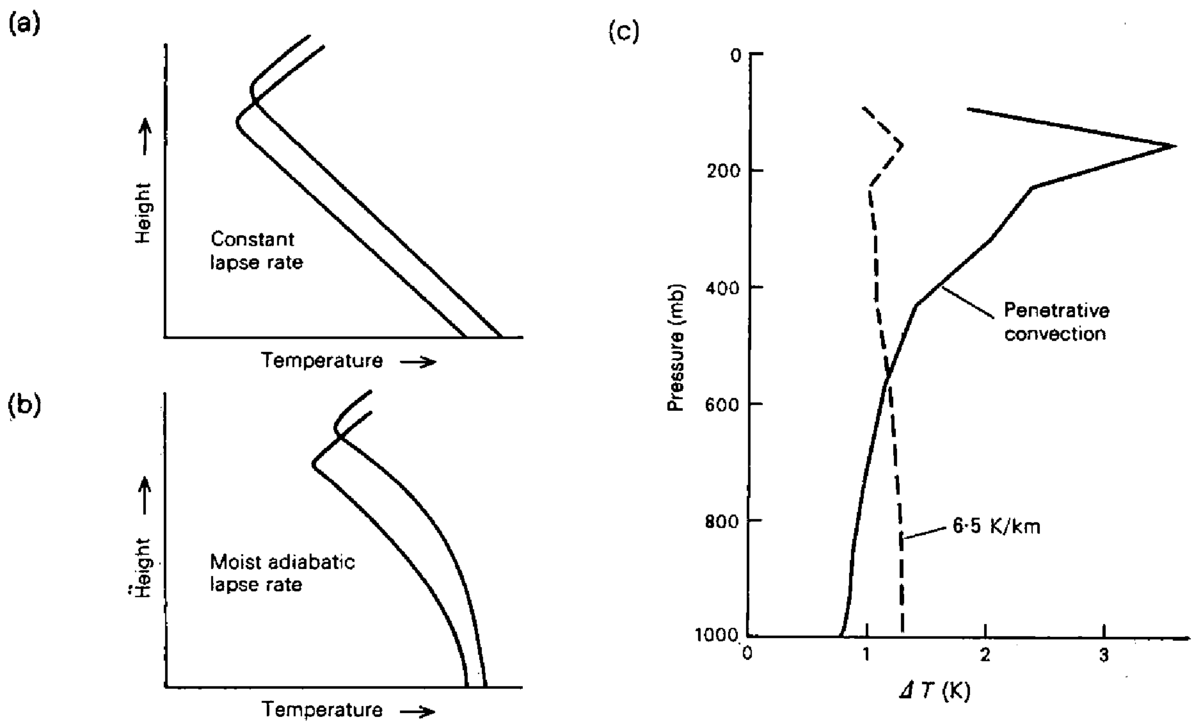


Figure 11—The effect of lapse rate on sensitivity to CO_2

(a) Constant lapse rate, normal and double CO_2 (schematic)

(b) Moist adiabatic lapse rate allowing for the release of latent heat, normal and double CO_2 (schematic).

(c) Changes in atmospheric temperature with height owing to a doubling of CO_2, in a radiative convective equilibrium model with no cloud and fixed absolute humidity. Dashed line —6.5 K/km lapse rate. Solid line—penetrative convection, allowing for the release of latent heat.

TABLE I—TYPICAL SURFACE TEMPERATURE INCREASES FOLLOWING A DOUBLING OF CO_2 IN A RADIATIVE-CONVECTIVE EQUILIBRIUM MODEL

Humidity	Cloud	Lapse rate constant (6.5 K/m)	Lapse rate adjusted for latent heat (penetrative) convection)
Fixed absolute	None	1.29	0.78
Fixed relative	None	2.46	1.70
Fixed relative	Average cloud (3 layers)	2.20	1.40

generally increases evaporation, it is unlikely that the absolute humidity of the atmosphere will remain constant. Observations of zonal mean relative humidity change little with season, so in many of the one-dimensional studies of climate, relative rather than absolute humidity is prescribed. The rise in tropospheric temperature due to CO_2 is then accompanied by an increase in water vapour, which further increases the opacity of the atmosphere to long-wave radiation and amplifies the rise in temperature at the surface, (Table 2, rows 1 and 2). The additional increase in the downward flux of longwave radiation at the surface is typically 12 W m^{-2}, or several times the initial increase due to CO_2.

TABLE 2—GLOBAL MEAN CHANGES FOLLOWING AN INCREASE IN CO_2 BY FACTORS OF 2 AND 10 (PRESENT-DAY SEA SURFACE TEMPERATURES) AVERAGED OVER ONE ANNUAL CYCLE

	$CO_2 \times 2$	$CO_2 \times 10$
Tropospheric temperature (K)	0.32	0.93
Surface temperature (K)	0.16	0.61
Land surface temperature (K)	0.41	1.71
Precipitation (%)	$-2\frac{1}{2}$	$-7\frac{1}{2}$
Heat flux into the ocean (W m^{-2})	5	17

The presence of cloud at prescribed altitude reduces the sensitivity to variations in CO_2 (Table 1, rows 2 and 3). Clouds absorb long-wave radiation at all wavelengths and so compete with CO_2 for the available radiation. When clouds are included with a penetrative convection scheme, the reduction in sensitivity is greater because the large temperature increase at the top of the atmosphere is reduced by high cloud cooling directly to space.

The results demonstrate that the sensitivity of one-dimensional models to changes in CO_2 depend very much on the formulation of the model. Furthermore most of the factors governing climate, such as atmospheric composition, clouds, extent of sea ice, orography, ocean temperatures, reflectivity of the surface, shown schematically in Figure 12, cannot be represented in one-dimensional models. At best, simple models predict changes which represent some kind of global mean. What is of interest is the change of climate at a given place in a given season, and 3-dimensional models of the atmosphere, oceans and cryosphere provide the most promising means of doing this (Mason 1976, Gilchrist 1978).

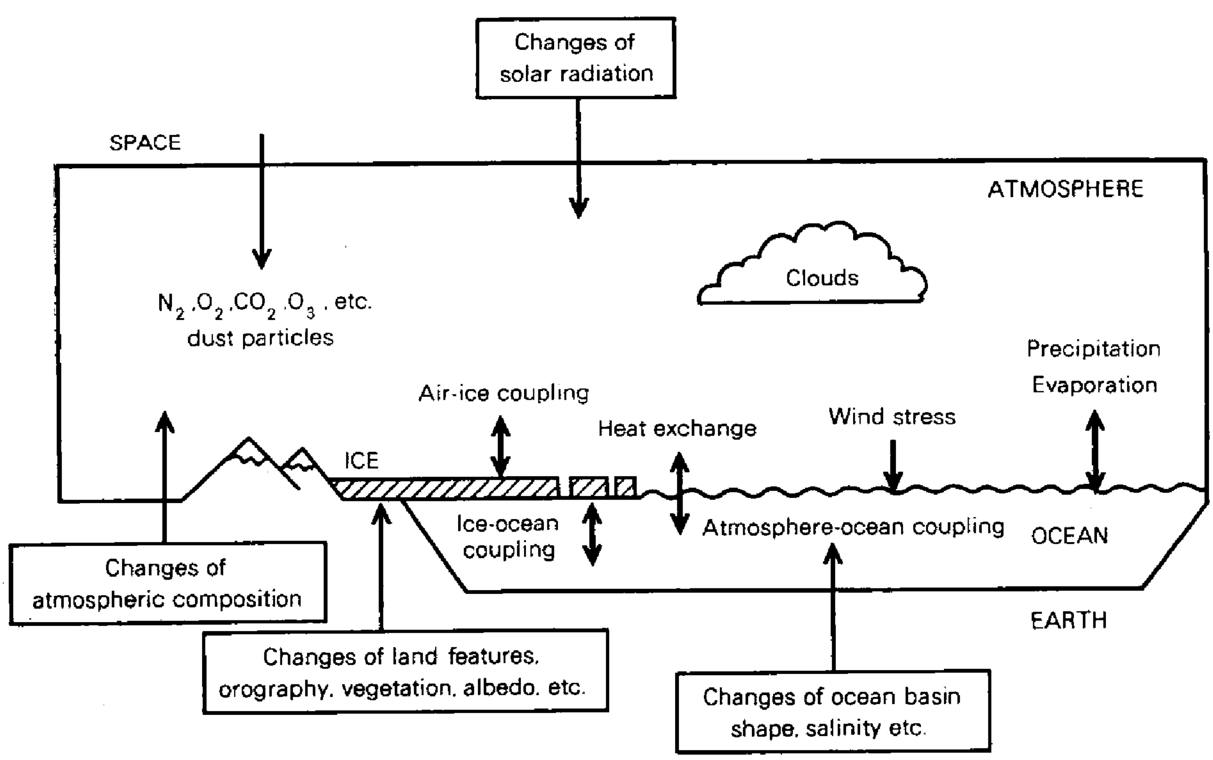


Figure 12—Physical processes and properties that govern global climate and its changes (from US National Academy of Sciences 1975)

Three-dimensional models

In an atmospheric numerical model, values of temperature, humidity and wind are stored at points on a horizontal grid at several levels in the atmosphere. These values are allowed to evolve in time by solving the equations of motion and thermodynamics at each point, subject to the constraints that the atmosphere remains hydrostatic and mass, heat and moisture are conserved. These grid points are typically 200 to 500 km apart in the horizontal, so many of the physical processes such as radiation, precipitation and the exchange of momentum, heat, and moisture at the surface cannot be represented explicitly. Instead their statistical effect is represented in a simplified manner using 'parametrizations' where formulations are based on observations made in the real atmosphere or the laboratory, or on numerical experiments with more detailed mathematical models. Once certain boundary conditions including the distribution of sea surface temperatures and sea ice, orography and the time of year have been prescribed, the atmospheric model can be stepped forward in time over the period of interest, which may range from a month upwards.

The quality of the simulation may be assessed by comparing the model data with climatological data for the relevant time of year. A more stringent test is to proceed through one or more annual cycles, to ensure that the parametrizations are valid over a range of climatic regimes. This is particularly useful if the model is to be used to assess changes in climate which are relatively small compared with the changes in the seasonal cycle as is the case for CO_2. An example from such a multi-year integration, the distribution of winter precipitation simulated by the Meteorological Office 5-level model, is shown in Figure 13. All the main features of the observed distribution are represented, including the regions of heavy precipitation associated with the continental heat lows over tropical South America, South Africa and Australia, and along the depression tracks in northern and southern mid-latitudes, and the drier regions in the subtropics.

The direct effect of increasing CO_2 is to warm both the atmosphere and the surface. As over three-quarters of the globe is covered by the oceans and sea ice, they too must be included in a model which is to be used to assess changes in climate. Experiments on the CO_2 problem carried out in the United States have followed the approach of using a highly simplified but interactive representation of the ocean linked to more complete atmospheric models. Their simulation of the present climate however is deficient, as factors such as the seasonal cycle and the transport of heat in the oceans have not been taken into account adequately. Studies made in the Dynamical Climatology Branch of the Meteorological Office have followed a different strategy (Mitchell 1983). The oceans influence the atmosphere through their surface temperatures. Models of the oceans are not yet capable of simulating the ocean circulations and vertical profiles of temperature and salinity well enough to determine the surface temperature with sufficient accuracy. In their absence, realistic simulations of climate require the sea surface temperatures to be specified; there is then an implied flux of heat in the oceans. In order to treat the effect of CO_2 as a perturbation on the present climate, the sea surface temperatures were held at the present-day value, and CO_2 was increased by factors of 2 and 10. In a second study, CO_2 was doubled and ocean surface temperatures were given a prescribed increase of 2 K everywhere, this increase being chosen as an estimate of the equilibrium effect of CO_2 doubling on the oceans. In a third study, not yet completed, CO_2 was increased and sea surface temperatures were given a

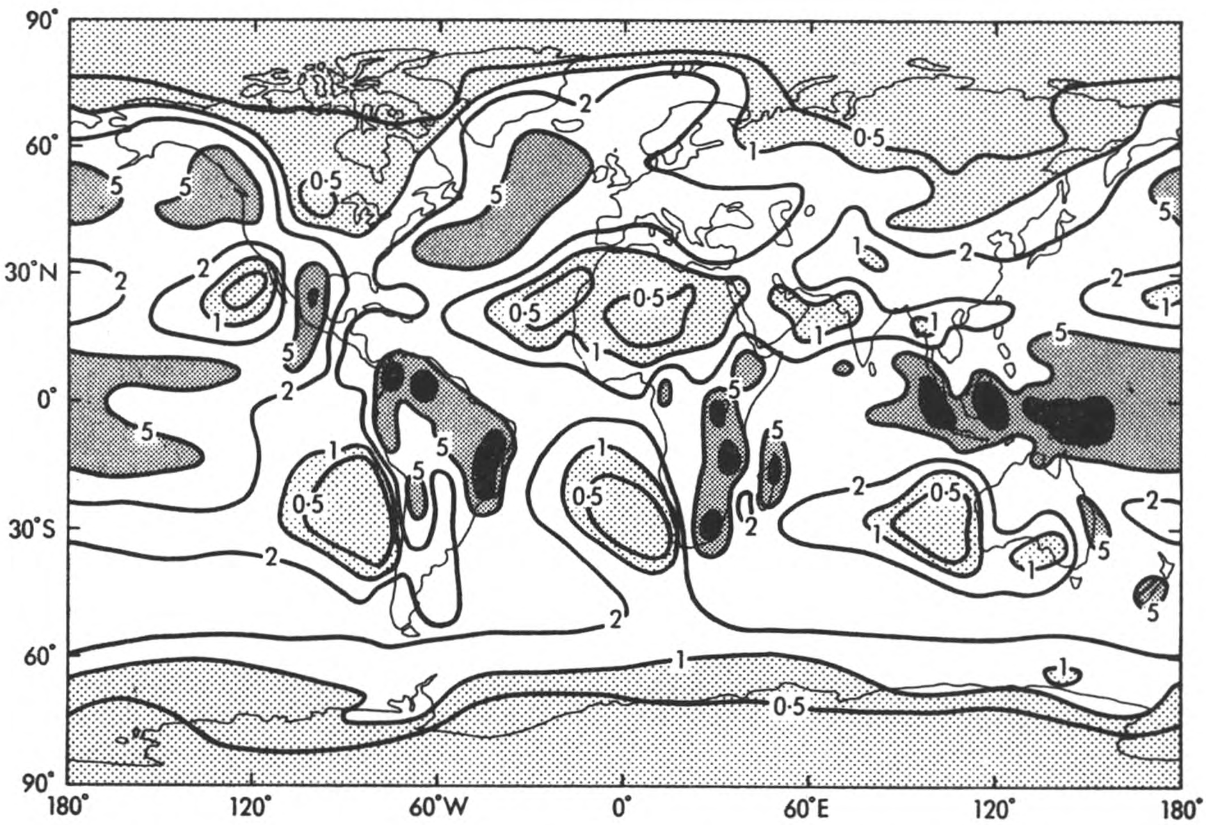


Figure 13—Total precipitation (mm/day), December to February, averaged over three years of a simulation made with the Meteorological Office 5-layer model

Light stippling—less than 1 mm/day. Heavy stippling—5–10 mm/day. Heavy shading—more than 10 mm/day. Additional contours at 0.5 and 2 mm/day.

latitude-dependent increase chosen using evidence mainly from the previous two studies. The advantage of prescribing sea surface temperatures is that the control simulation is superior to those produced by models with simplified representation of the ocean. In both control and anomaly simulations the transport of heat by the ocean is included implicitly, and the longitudinal gradients of sea surface temperature are preserved, consistent with the assumption that changes due to CO_2 may be treated as perturbations. These considerations are important for the determination of regional changes in climate. Of course one cannot then deduce the magnitude of the global mean temperature rise associated with an increase in CO_2, as this depends on the value specified for the oceans.

The oceans, which have a thermal capacity of about a thousand times that of the atmosphere, are expected to delay the response of climate to CO_2 changes. It is believed that the top 100 or so metres of the ocean respond to changes in surface heating on the time scale of a decade, whereas the deeper ocean may take several centuries to approach equilibrium. In the first of the experiments outlined above, CO_2 was doubled but the sea surface temperatures were prescribed at their present day values in order to assess the effect of increasing CO_2 in the absence of a response by the ocean. The increase in global mean tropospheric temperature over that found in the control (see Figure 14) fluctuates as a result of the model variability. The results from a further integration, also shown in Figure 14, in which CO_2 is increased by a factor of 10, produces a much larger increase in temperature. The rise in global annual mean surface

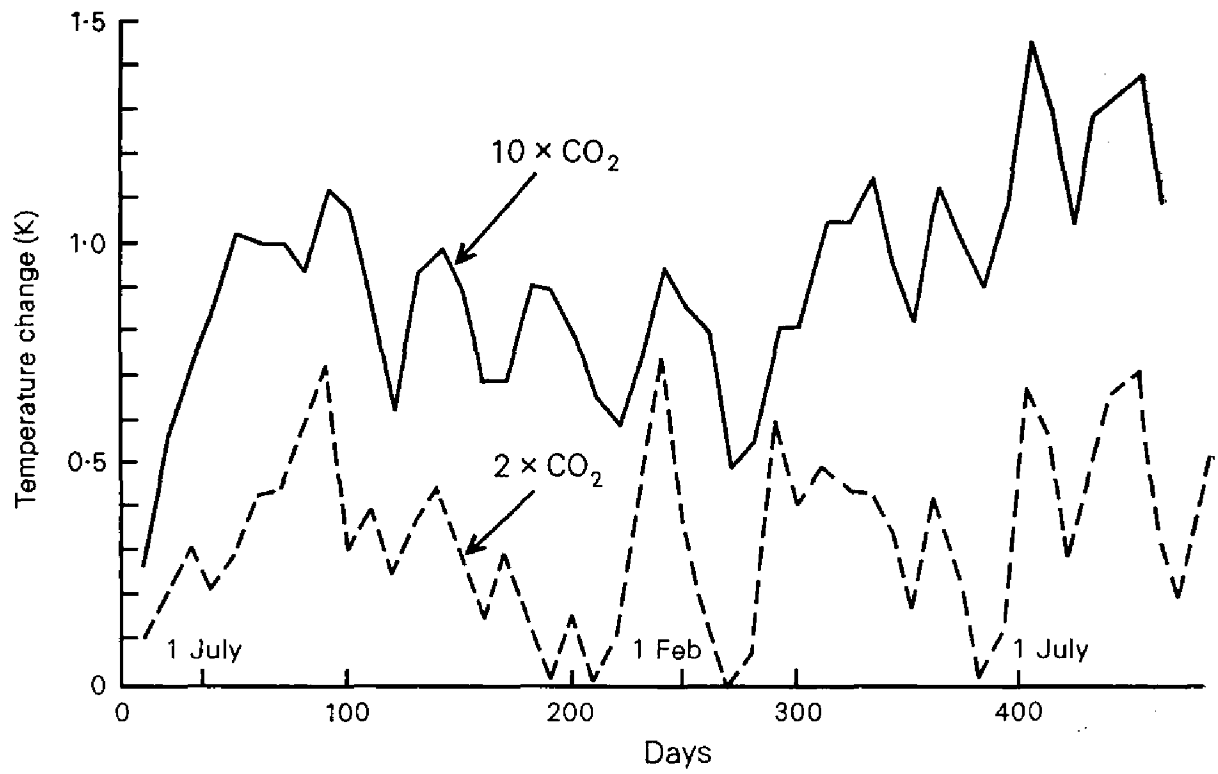


Figure 14—Changes in global mean tropospheric temperature owing to an increase in CO_2, with present-day sea surface temperatures

Dashed line—CO_2 concentration increased by a factor of 2. Solid line—CO_2 concentration increased by a factor of 10.

temperature (see Table 2) varies approximately logarithmically with the CO_2 concentration (in this case 1:3.3) as suggested by other work in the United States by Augustsson and Ramanathan (1977). Not only are the responses in Figure 14 well above the model's 'noise' level, but also the response varies in the expected manner as CO_2 is increased. The increase in atmospheric temperature increases the low-level static stability over the oceans since the surface temperature is unchanged, and reduces the flux of sensible and latent heat from the surface. In other words, the heat flux into the ocean from the atmosphere is increased (see Table 2). This would lead to an increase in sea surface temperature, as demonstrated by researchers in the United States using climate models with a simple ocean (e.g. Manabe and Stouffer 1980).

In order to assess the main effect of the rise in ocean temperature which is expected to accompany an increase in CO_2, a further integration has been made in which CO_2 amounts were doubled and the ocean surface temperature was increased by 2 K everywhere. The magnitude of the sea surface temperature increase was chosen on the basis of one-dimensional experiments and integrations made with simple models elsewhere.

The raising of the ocean temperature leads directly to an increase in evaporation from the ocean which removes heat from the surface and tends to balance the increase in radiative heating from CO_2 (and water vapour). It should be noted that the direct heating of the atmosphere by conduction from the ocean surface was reduced, even though the ocean temperatures were raised. The increase in evaporation is necessarily accompanied by an increase in precipitation which warms the troposphere through the release of latent heat, increasing its capacity to hold water vapour (see Table 3).

TABLE 3—GLOBAL MEANS FROM CONTROL INTEGRATION, AND THE CHANGES INDUCED BY DOUBLING CO_2 AND INCREASING SEA SURFACE TEMPERATURE BY 2 K

	Two-year mean	Change
Tropospheric temperature (K)	-12.20	3.02
Land surface temperature (K)	3.03	2.86
Precipitation (mm/day)	2.83	0.14
Atmospheric water content (g/kg)	3.16	0.56

Although the model's global mean precipitation rate increases when CO_2 is doubled and sea surface temperatures are increased, there are also regions which become drier (see Figure 15 (a)). Most of the increases occur along the depression tracks and on the eastern side of the continental heat lows where precipitation is already heavy, as may be verified by comparing Figures 14 and 15(a) which show respectively precipitation and changes in precipitation during the northern hemisphere winter. This is to be expected as the increase in atmospheric moisture increases the supply of moisture to the existing regions of convergence and the changes in low-level flow are small. Clearly, before the model can represent changes in climate correctly, it must reproduce the present climate correctly. As discussed earlier, this is the reason for choosing a model which reproduces present-day climate most accurately, rather than a simpler model in which the response is not in any way prescribed, but the control climate is deficient. Not all the changes in Figure 15 (a) can be explained in terms of the increase in atmospheric moisture and the existing flow patterns. For example, the precipitation maximum over southern Europe is actually reduced.

The changes in the model also vary with time of year, as may be seen by comparing Figure 15 (a) with Figure 15 (b), which shows the changes in precipitation during the northern hemisphere summer in the same experiment. For instance, the increases in precipitation over the eastern coast of South America, South Africa and Australia have now disappeared, but the eastern United States and south-east Asia have become wetter.

Although we have prescribed an increase in sea surface temperature which is constant, there are considerable variations in the surface temperature of the continents through the year. In particular, temperature rises in middle and high latitudes in the northern hemisphere are largest in winter (see Figure 16 (a)), owing to an increase in the flow of air and the warm oceans, and the poleward retreat of the snowline. In the summer hemisphere, some of the largest rises in temperature occur in dry regions, notably central South America and southern Africa, (see Figure 16 (a)) and the Sahara (see Figure 16 (b)), as the evaporation from the surface is limited by soil moisture, and most of the increase in radiative heating is used to increase the surface temperature.

A further integration in which CO_2 was increased and the sea surface temperature changes were prescribed as an increasing function of latitude, has just been completed. The changes in sea surface temperature were chosen in the light of previous integrations, and for consistency, the sea ice extents were also reduced. A preliminary analysis indicates that the changes in precipitation and temperature are qualitatively similar to those depicted in Figures 15 and 16, although the rises in surface temperature over the continents are relatively larger in high latitudes, as might be expected from the reduction in sea ice and the nature of changes in sea temperature.

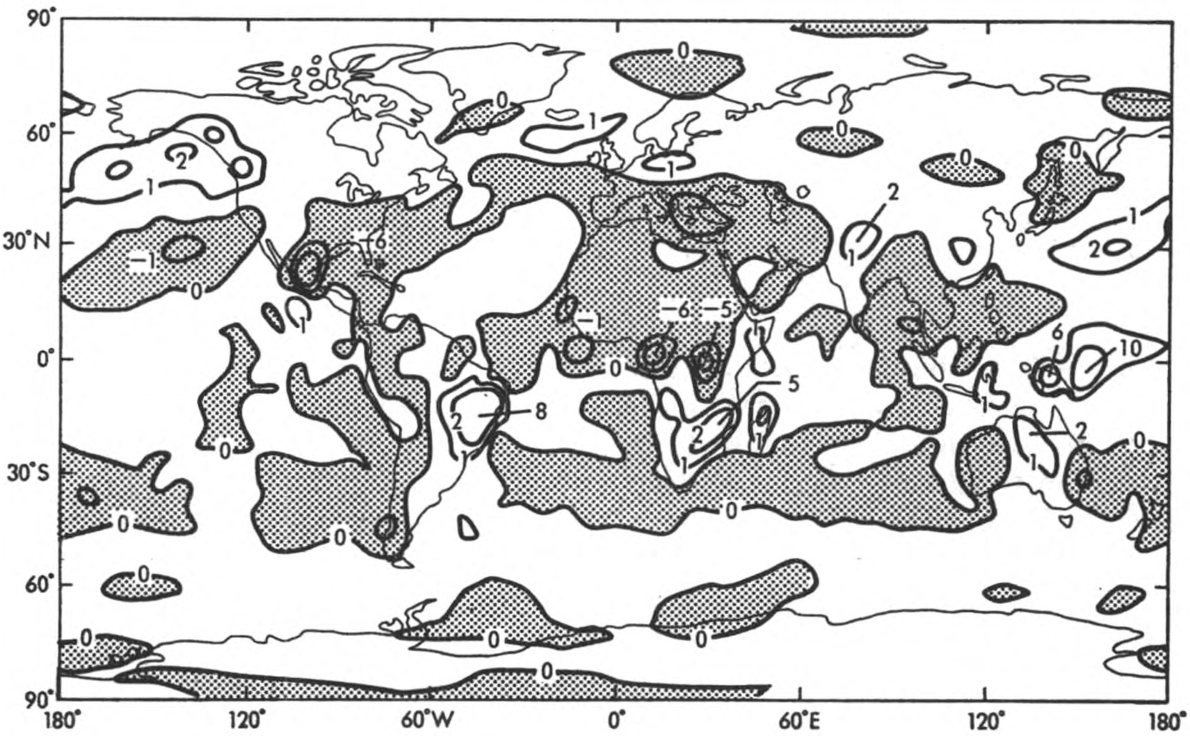


Figure 15(a)—Changes in model precipitation (mm/day), December to February, owing to doubling CO_2 and increasing sea surface temperatures by 2 °C

Areas of decreases are stippled and contours are shown at 0, ±1 and ±2 mm/day.

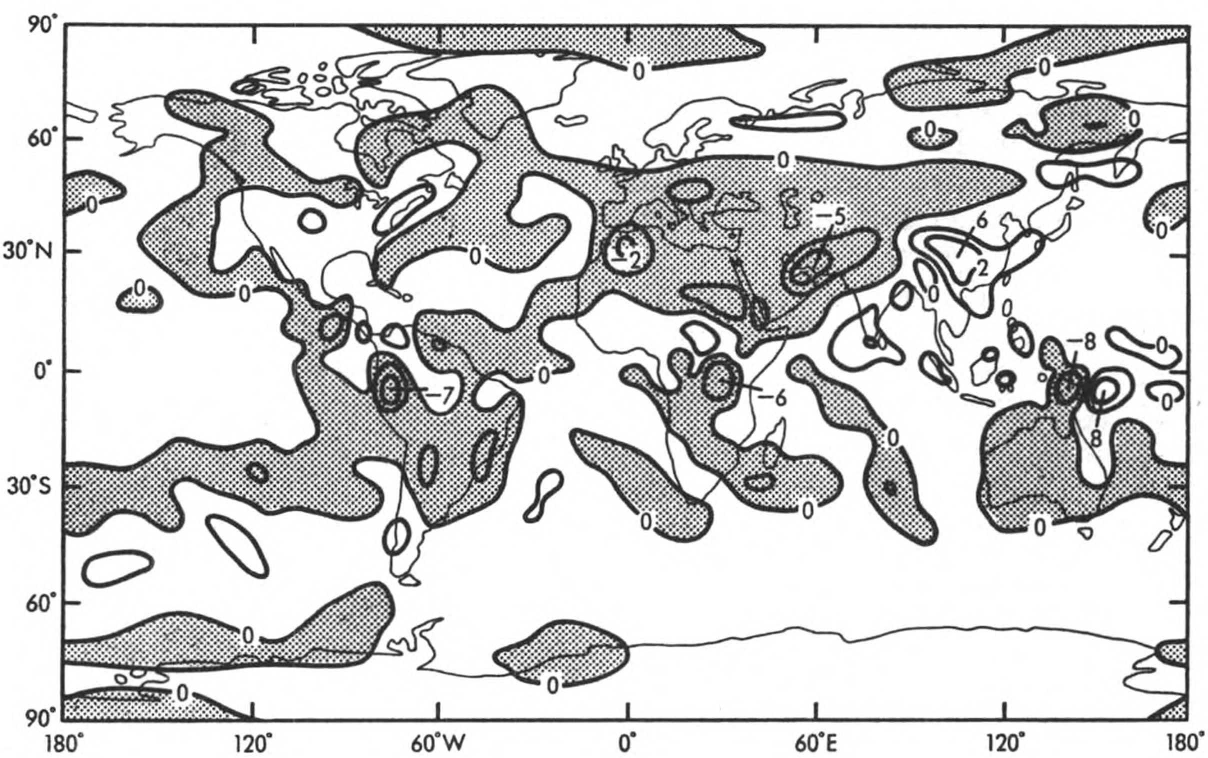


Figure 15(b)—As for Figure 15(a) but for June to August

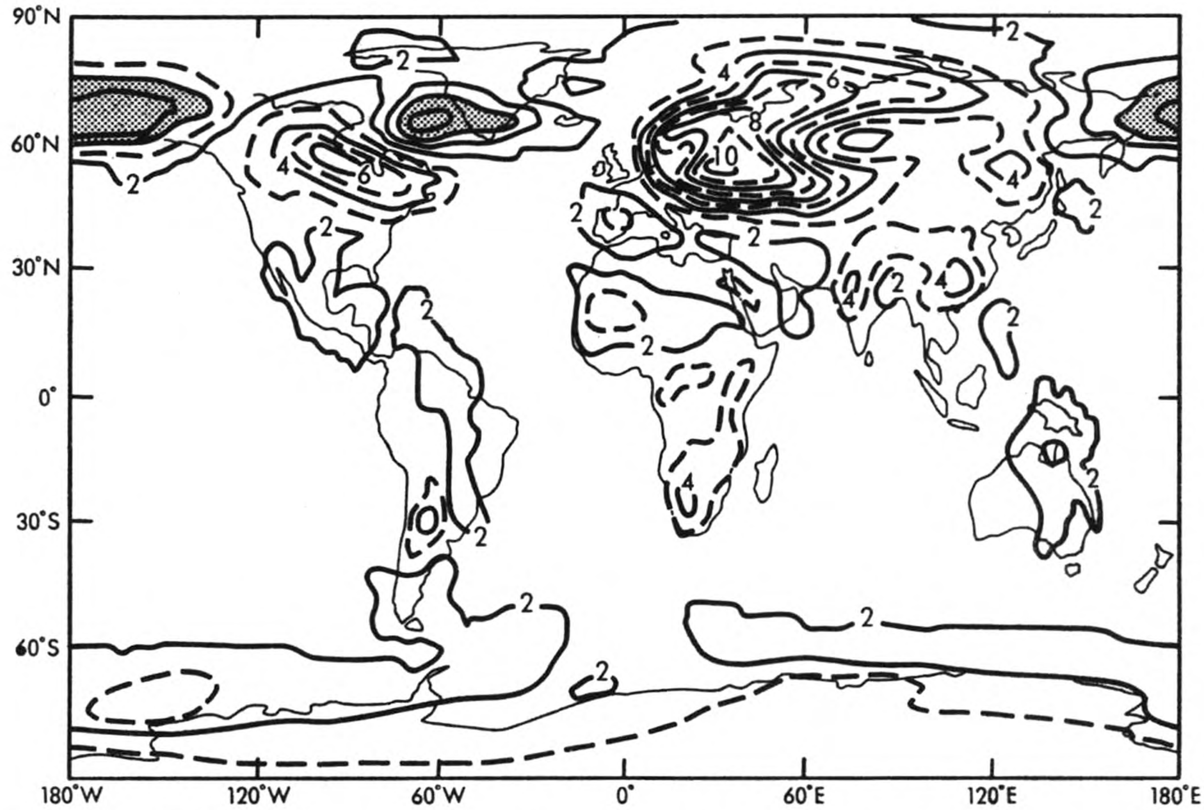


Figure 16(a)—Changes in model surface temperature (°C), December to February, owing to doubling CO_2 and increasing sea surface temperatures by 2 °C

Areas of decrease are stippled. Solid contours at –1, 0, 2, 4, 6, 8 and 10. Dashed contours at 1, 3, 5, 7 and 9.

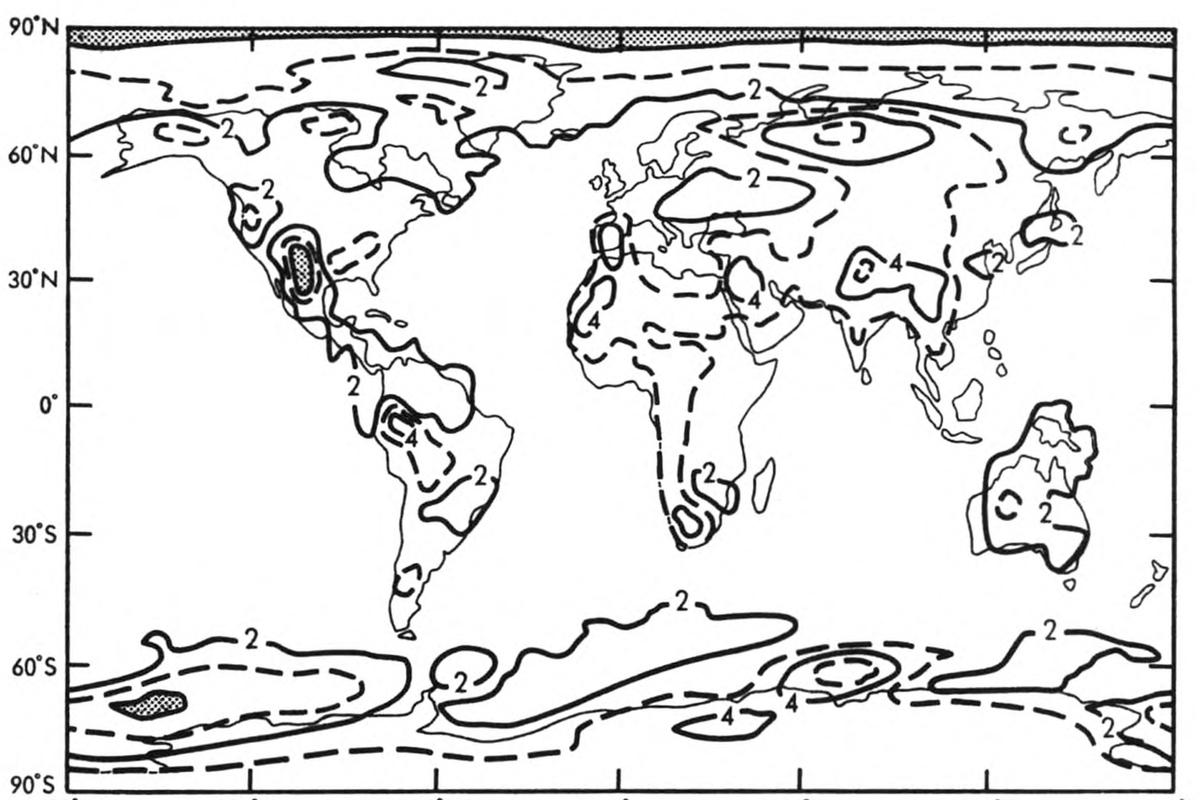


Figure 16(b)—As for Figure 16(a) but for June to August

Future work

The investigations carried out so far have provided valuable information concerning the possible changes in climate accompanying an increase in CO_2, and the physical processes leading to those changes. However, they are only the first stage in a continuing program of research to elucidate this difficult problem. The present work is being extended in three ways.

First, a full climate model is being developed in the Dynamical Climatology Branch. A new version of the atmospheric model has recently been set up on the CYBER 205 computer, and is being tested and improved. At present, cloud amounts are prescribed from climatology. It is possible that changes in cloudiness could damp or amplify the response of climate to variations in CO_2. Whereas it is fairly obvious that ocean temperatures will rise with increases in CO_2, one cannot predict even the sign of changes in cloudiness. A scheme which calculates cloud amount from model variables has been included in the atmospheric model. This scheme will not be used in climate-change experiments until it has been thoroughly tested in an integration through one or more annual cycles. Although the investigations made with prescribed surface temperature changes have proved useful, further progress would be limited without some form of ocean model. There already exist in the Dynamical Climatology Branch both simple models of the upper layers of the ocean and sea ice, and more complex models which incorporate both the dynamics and thermodynamics of the full ocean, and these will be coupled to the atmospheric model for future studies of CO_2 and climate.

Second, some consideration will be given to the transient response of climate to changes in atmospheric CO_2. Until now, most research has concentrated on determining the equilibrium climate following a prescribed increase in CO_2. There are indications that the ocean surface temperature will respond at different rates in different latitudes to increases in CO_2, and this will influence the response over the continents.

Third, future studies will attempt not only to predict mean changes in climate in a given region at a given time of year, but also the changes in frequency of events which have direct economic consequences such as frost, floods and gales. This cannot be achieved until the models produce a better simulation of present day climate, and will require long integration with fine horizontal resolution. Some of this work is being supported by the EEC Climate Program.

The numerical models in which the research is based have been developed for a wide variety of investigations including research on the general circulation of the atmosphere, on climate and climate variability, and on climatic change caused by factors in addition to CO_2. Some of the parametrizations and techniques have gained applications in other fields; for example, within the new operational forecast system. Progress on the CO_2 problem will depend on progress in understanding climate more generally and particularly on two outstanding areas—namely, modelling the oceans and the interaction of cloud and radiation.

REFERENCES

Augustsson, T. and Ramanathan, V. 1977 A radiative-convective model study of the CO_2 climate problem. *J Atmos Sci*, **34**, 448–451.

Callendar, G. S. 1938 The artificial production of carbon dioxide and its influence on temperature. *Q J R Meteorol Soc*, **64**, 223–237.

Gilchrist, A. 1978 Numerical simulation of climate and climatic change. *Nature*, **276**, 342–345.

Hansen, J., Johnson, D., Lacis, A., Lebedeff, S., Lee, P., Rind, D. and Russell, G. 1981 Climate impact of increasing atmospheric carbon dioxide. *Science*, **213**, 957–966.

Keeling, C. D. 1982 The global carbon cycle: What we know and could know from atmospheric, biospheric and oceanic observations. (Review paper presented at US Department of Energy meeting, Carbon Dioxide, Science and Consensus, held at the Coolfont Conference Center, West Virginia, 19–23 September 1982.)

Manabe, S. and Stouffer, R. J. 1980 Sensitivity of a global climate model to an increase of CO_2 concentration in the atmosphere. *J Geophys Res*, **85**, 5529–5554.

Mason, B. J. 1976 Towards the understanding and prediction of climatic variations. *Q J R Meteorol Soc*, **102**, 473–498.

Mitchell, J. F. B. (1983) The seasonal response of a general circulation model to changes in CO_2 and sea surface temperatures. *Q J R Meteorol Soc* (in press).

Roach, W. T. and Slingo, A. 1979 A high resolution infrared radiative transfer scheme to study the interaction of radiation with cloud. *Q J R Meteorol Soc*, **105**, 603–614.

Rowntree, P. R. and Walker, J. 1978 The effects of doubling the CO_2 concentration on radiative-convective equilibrium. *In* Williams, J., Carbon dioxide, climate and society: Proceedings of a IIASA Workshop cosponsored by WMO, UNEP and SCOPE, February 21–24, 1978. Oxford, Pergamon Press, 181–191.

US National Academy of Sciences 1975 Understanding climatic change: A program for action. Washington, National Academy of Sciences, National Research Council, US Committee for GARP.

OTHER WORK OF THE DIRECTORATE OF RESEARCH

Physical Research

Cloud physics

The presence of water, in solid, liquid or vapour phase has an important effect on the chemical and physical processes which occur in the atmosphere. Studies of clouds and precipitation are therefore relevant to many of the activities of the Meteorological Office. The research is directly relevant to the forecasting of different forms of precipitation and also to such problems as forecasting the occurrence and dissipation of fog. The research also provides information which is required for engineering design purposes and examples where progress has been made include the probability of occurrence of extremes of precipitation and the incidence of aircraft icing in clouds. Clouds and water vapour influence the transmission of radiation through the atmosphere over a range of wavelengths. Since clouds will modify the local radiative heating or cooling of the atmosphere a knowledge of the basic processes is important for assessing the problems of climatic change. The sensitivity of transmission to the presence of water vapour is also a problem for the designer of instruments for remote sounding of the atmosphere. The effects of water are determined largely by its phase but this is difficult to predict because phase transitions occur under conditions far removed from equilibrium. A combined laboratory, observational, analytical and numerical approach is necessary if the underlying mechanisms are to be properly understood and advice given on the solution of practical problems.

Although laboratory and analytical investigations have formed the basis of hypotheses concerning the growth of cloud particles and the dynamical interactions between clouds and their environment, many of the ideas have not been tested against atmospheric data. A major part of the work during the past year has involved the use of the Hercules aircraft of the Meteorological Research Flight (MRF) and includes both the acquisition and interpretation of data from a variety of meteorological situations. The instrumentation installed on the aircraft enables a range of dynamical, thermodynamical and cloud microphysical measurements to be made along the flight path. Sondes can be ejected from the aircraft and these make it possible to derive the fields of temperature, humidity and horizontal wind components with a horizontal spatial resolution of about 25 km. Some development of the aircraft's instrumentation is taking place, for example a radiometer to give accurate temperature measurements in clouds is being developed. The interpretation of the aircraft measurements and of data obtained from radars, satellites and ground-based observing systems is being carried out using numerical models to test different hypotheses.

An analysis has been completed of observations of convection behind a cold front in which the convective cloud was organized in bands. A banded cloud structure is frequently observed in the vicinity of fronts and clarification of the mechanisms leading to these structures is important if precipitation is to be accurately forecast. The data included drop-sonde observations along a line perpendicular to the bands and microphysical measurements at three levels in the bands in addition to satellite imagery showing the effects of large-scale advection and development. Numerical models have been used to predict the values of observed parameters which would arise from different theoretical models of the organizing mechanism. It has been demonstrated that conditional symmetric instability, in which convection is released by mesoscale roll instabilities in a baroclinic zone, is consistent with the observations. A crucial factor in isolating this mechanism was the agreement between the observed and predicted velocity of propagation of the bands relative to the mean flow. Analysis of the microphysical data obtained in this case study has demonstrated that the ice crystal concentration in the clouds may be significantly affected by entrainment of the residue from earlier decaying clouds. Preliminary work has started in an attempt to construct a mesoscale numerical model in which it will be possible to treat the effects of convection in frontal zones explicitly.

A number of investigations have been undertaken using a numerical model of deep convective cloud with the aim of identifying factors leading to very heavy surface rainfall. While some quantitative differences remain between predicted and observed surface rainfall rates on specific occasions, it has been demonstrated that heavy rain may result from the merging of clouds. In a closely defined range of conditions, when a vertical shear in the horizontal wind exists, the precipitation from one cloud may fall through another cloud growing close to the first cloud. The growth of the precipitation particles by accretion as they fall through the lower cloud gives rise to high surface rainfall rates.

Some data on the droplet size distributions in rain have been obtained from the aircraft and from the dual polarization radar operated at Chilbolton by the Rutherford Appleton Laboratory and it is expected that these studies will be continued and extended to clouds containing both ice and water particles. Analysis has continued of the data obtained in collaboration with several research groups in the Federal Republic of Germany during the KONTUR (KONvektion und TURbulenz) project over the North Sea. Measurements were made during several flights through deep convection which was organized into cellular patterns; these have been analysed and interpretation has commenced.

Studies of small cumulus clouds have been carried out to assess the mechanisms controlling the evolution of populations of water droplets and ice crystals in clouds. The observed rate of production of precipitation-sized particles in warm clouds (i.e. those containing no ice particles) is not fully understood despite considerable efforts over several years. Work over the past year has concentrated on the effects of entrainment between a cloud and its environment and various formulations of the entrainment mechanisms have been tested in numerical simulations. The results have shown that air entrained at cloud top may penetrate deeply into clouds giving rise to regions of low water content and low droplet concentrations. The presence of such regions, which has been demonstrated by aircraft observations, will clearly have some influence on droplet growth but calculated effects are generally small. Data from recent aircraft flights are being analysed in order to test the model predictions and to clarify the role of entrainment and the source of the entrained air. A factor which has been neglected in calculations of the evolution of cloud droplet spectra is departures from a random spatial distribution of the cloud droplets. Holograms of cloud droplets obtained using a camera system developed in the Cloud Physics Branch can be used to examine whether such departures occur and preliminary results suggest that while there may be significant clustering of the drops in orographic cloud close to the surface this is absent in well-mixed convective cloud.

Early observations in clouds suggested that it was often difficult to explain the observed concentrations of ice particles in clouds and a limited amount of work has been undertaken in an attempt to clarify the important processes. Holograms obtained in partially glaciated clouds have been analysed by a student at the Physics Department, University of Manchester Institute of Science and Technology (UMIST). It has been demonstrated that the transport of ice crystals from cooler higher regions is a very important factor in explaining the observations. Further work is being carried out on this problem in collaboration with UMIST since the problem is a crucial one when attempting to incorporate the effects of glaciation into cloud models.

Earlier investigations of the turbulent and radiative properties of stratiform clouds were largely concerned with localized measurements using balloon-borne instruments. These studies are being extended using the instrumented Hercules aircraft to investigate the effects of large-scale dynamical processes on the development of the cloud. Data from aircraft flights through maritime daytime clouds are being analysed and flights in nocturnal clouds are planned. Numerical modelling of the cloud is being carried out to demonstrate the role of the different processes. Microphysical measurements made during the flights are being used to investigate the crucial entrainment processes at the top of the cloud which can determine the persistence of the cloud.

The practical problem of ice accretion involves a statistical evaluation of the occurrence of clouds in addition to a knowledge of the microphysical properties of those clouds. Microphysical information obtained using the various cloud physics probes on the Hercules aircraft have been used to provide information on the vertical distribution of water in clouds. The data analysis has enabled empirical rules to be developed allowing the water content in stratiform cloud to be estimated as a function of the height above cloud base and the strength of the capping inversion. Measurements obtained in cumulus clouds are being analysed and show much more variation because of the increased effect of turbulent mixing compared with stratiform cloud. Some progress has been made in developing empirical prediction rules. Limited observations from clouds in which ice particles and water drops coexist are also being analysed to determine whether useful advice can be given to aircraft designers and others.

Development of a numerical model of radiation fog is almost complete. The model has been used to predict the occurrence of fog under certain conditions and these predictions are consistent with those obtained using empirical forecasting rules. A detailed verification of the model using extensive data sets available from several field projects has begun.

The atmospheric boundary layer

The atmospheric boundary layer may be defined qualitatively as the lowest layer of the atmosphere which is influenced directly by the underlying surface. It has very variable character and depth, ranging from a few tens of metres in stable conditions to perhaps a few kilometres in very unstable conditions. As a major energy source and momentum sink in the atmosphere it plays a vital role in the exchange of heat, moisture and momentum between the earth's surface and the 'free' atmosphere. It is also the layer which is the scene of most of man's activities and, in particular, it is the turbulent nature of this region which determines primarily the transport, dispersion and deposition of most atmospheric pollutants.

For several years the Boundary Layer Branch (split between Bracknell and

Cardington, Bedfordshire) has made theoretical studies and has conducted a complementary series of experiments (both field and numerical) to improve understanding of the effects of hills on the boundary-layer flow. Following the success of previous experiments, a major field expedition was mounted, during a six-week period in September–October, on and around an isolated hill, Blashaval (109 m), on North Uist in the Outer Hebrides. The aim was to obtain 'the definitive data set' needed to discriminate between the various existing, conflicting theories that attempt to explain the nature of the air flow in the boundary layer over isolated, 'three-dimensional' hills. The net effect of the hill depends critically on the character of the turbulence generated and only with a carefully chosen, uniformly shaped and relatively smooth isolated hill such as Blashaval is it possible, at this stage, to obtain meaningful statistics.

For this experiment improved instruments were designed, constructed and ultimately deployed up to 16 m from the surface on an array of masts, distributed upstream of and on the hillside, to provide measurements of mean-wind flow and temperature profiles and the characteristics of the near-surface turbulence. Many useful turbulence data of the required quality appear to have been recorded. A small TALA kite was flown successfully on several occasions to obtain wind profiles up to 200 m. All the instrumentation performed remarkably well considering its prolonged exposure to often extremely wet and windy conditions.

Data continue to be processed and interpreted from recent expeditions, such as those in 1980–81 to study the flow over the effectively two-dimensional, valley-ridge system of the Sirhowy Valley in South Wales. On such occasions data from surface-based instruments were supplemented to a very significant extent with data obtained with the instrumented Hercules aircraft of the Meteorological Research Flight (MRF). Indeed, aircraft data exclusively are being analysed in connection with a more recent study of the three-dimensional, boundary-layer flow around the isolated island of Foula in the Shetland Isles. The emphasis here is to determine the distortion of the airflow due to the island's presence. Such data are being used to assess and influence the development of theories and numerical models of flow over hills.

Boundary layers over land in less complex terrain also continue to command attention. The stable boundary layer poses many challenging questions for both experimentalists and theoreticians. Analysis of the data from the new Mean Value Probe used during the 1981 Fens experiment has produced an interesting series of wind and temperature profiles with clear indication of the development of surface-based inversions and nocturnal jets. However, the analysed scales of turbulence were smaller than expected and so a further set of field data was collected at Cardington during Spring 1982.

A new, improved Lyman–Alpha, wet- and dry-temperature device has been developed for probing the temperature and humidity structure of cloudy boundary layers and some interesting and intriguing results have already been obtained in trials. For example, on occasions distinctive, thin, dry layers, which exhibit marked diurnal evolution, have been sensed just above a layer of maritime stratus cloud. None of the existing theories is able to account quantitatively for these observations which are particularly difficult to interpret because of the apparent variability of the humidity profiles above the cloud.

It is generally acknowledged that the atmospheric boundary layer over the sea behaves differently, and must generally be treated differently, from that over the land. For many years the Meteorological Office has devoted considerable expertise and experimental resources, notably the MRF Hercules aircraft and instrumented tethered balloons, to observational studies of the boundary layer over the sea. This year studies have concentrated largely on analyses of data obtained in previous years. Results from the Joint Air–Sea Interaction Experiment (JASIN) are described in the following section. Good progress has been made with the processing and analysis of data from the KONTUR (KONvektion und TURbulenz) experiment, a study of convective boundary layers which took place, in collaboration with scientists at several German research institutes, in the German Bight during Autumn 1981. In particular, the properties of the boundary layer are being classified according to whether cloud streets were observed or whether open or closed cellular convection prevailed. Data from inter-comparison flights have already been exchanged.

Pollution is released into the atmosphere from a wide range of industrial sources, and, occasionally, short-duration releases of toxic, inflammable or pollutant substances occur by accident. An increasingly important function of the Meteorological Office is to provide advice on how such materials will be transported, dispersed and deposited. Dispersion is a complex process and depends, amongst other things, on the characteristics of the source, the boundary-layer mean and turbulent properties and processes, and the nature of the underlying topography. A wide range of spatial scales is involved and calculation of the concentration of pollutants within a few kilometres of the source (short range) requires different considerations from those used to estimate trajectories and dispersion of plumes over several hundred kilometres (long range).

An established method of modelling short-range dispersion is the so-called 'random walk' technique. Such a model, used previously only for conditions of neutral stability, has been adapted successfully for application to both stable and convective conditions. In non-neutral conditions unrealistic concentrations of particles were found to occur at some levels in the model owing to the variation with height in the scales of turbulent velocity used. This discovery led to the development of a new theory involving the accelerations caused by the turbulent, Reynolds stresses and to a corrected version of the model which yielded concentrations which were in good agreement with experimental data.

In support of the theoretical and numerical modelling studies a primary objective is to develop and establish a technique for making our own reliable dispersion measurements over short and medium ranges. Several particularly promising trials have been carried out with a system which can use harmless 'dry-cleaning' fluids as tracer gases. The dosage downwind of a source is measured by exposing small discs ('badges') of absorbent material, mounted behind a porous membrane, such that the gases reach the disc passively, i.e. by molecular diffusion. Although still at an early stage of development, this system was tried out at Blashaval.

Long-range transport remains a topic of considerable interest arising mainly from concern over possible damage to the environment caused by 'acid rain' which results from pollution from fossil-fuelled industrial installations situated sometimes many hundreds or thousands of kilometres upstream. A joint experimental study of the long-range transport of pollutants across the North Sea has continued in collaboration with the Central Electricity Research Laboratories, Leatherhead. The main emphasis recently has been on the analysis of chemical and meteorological data gathered by the MRF Hercules aircraft which is used to track 'labelled' plumes from particular sources for long distances over the North Sea. There is evidence that mesoscale topographic features inland and near the coast may, on occasions, play an important role in the transport of the plume and that plume growth over land is much more variable than over the sea. Further flights are planned to study these aspects in more detail.

There has been further development of a simple model to simulate the emission–transport–conversion–deposition cycle of industrial pollutants in Europe. The model is being used to assess the need for much more complex (and therefore more costly) models used by some other groups. It is currently being used to test whether allowances which can be made for the patchy, rather than continuous, nature of rainfall, and improvement in the representation of the process of wet deposition, are likely to improve significantly the performances of the more realistic trajectory models.

JASIN

The Joint Air–Sea Interaction Experiment (JASIN) was designed to observe the physical processes causing mixing and to quantify aspects of the heat and momentum budgets in mid-latitude oceanic and marine atmospheric boundary layers. The project was planned on the assumption that an improved knowledge of the structure of the atmospheric boundary layer over the sea and the transfer processes within it would be of value to those designing numerical models of the atmosphere and its general circulation. A corresponding knowledge of the structure and mechanics of the upper mixed layer of the ocean is also essential in ocean modelling and for the coupled atmosphere–ocean models that are increasingly used to study climatic variation. The results summarized here were presented at a two-day Royal Society discussion meeting in June 1982.

The multiplicity of processes to be sampled necessitated a large experiment and JASIN involved a large multinational team of investigators working from 14 ships and 3 aircraft, including the Meteorological Research Flight (MRF) Hercules. Scientists from MRF and the Cloud Physics Branch of the Meteorological Office played the leading role in organizing the aircraft program and staff from the Boundary Layer Branch were based on HMS *Hecla* to fly a tethered balloon turbulence probe and launch radiosondes. The experiment took place from July to September 1978 in the North Rockall Trough, an area of deep water several hundred kilometres off the west coast of Scotland.

Hydrographic surveys revealed mesoscale eddies 100 km across and a series of intensive measurements on successively smaller scales revealed fronts in the confluence zones of the eddy field. The development of the oceanic mixed layer and seasonal thermocline, internal and inertial wave fields and the response of the mixed layers to atmospheric forcing were all complicated by these structures.

Transfer processes at the air–sea interface were measured by a variety of techniques from ships, buoys, aircraft and microwave remote sensing instruments on the SEASAT A satellite. The results of intercomparisons between the remotely sensed data and those obtained by more conventional techniques were particularly encouraging and enabled the spatial and temporal variation of the sea surface fluxes of heat, water vapour and momentum to be examined in relation to synoptic-scale features. Generally, the heat flux was found to be less than 25 per cent of the latent heat flux and over periods of a day the total upward heat flux was about half the incoming net radiation implying that a significant proportion of the available heating went into the upper layers of the ocean.

The structure of the atmospheric boundary layer on scales of 200 km was investigated by regular radiosonde launches from ships stationed at the vertices of a triangle. On certain days an hourly launch rate was maintained which subsequently enabled budgets of mass, momentum, sensible and latent heat to be constructed. On these scales, the boundary layer was found to be non-steady, inhomogeneous and generally close to neutral stability, a common situation over the mid-latitude oceans which previously had attracted little observational investigation. If the budget residuals are interpreted as being due to small scale turbulent transfer, they imply significant momentum and latent heat transfer throughout the depth of the boundary layer, extending to the lowest inversion base, which usually coincided with cloud top.

A rather different impression is conveyed by the results from the tethered balloons and aircraft which made direct measurements of the turbulent fluctuations. These investigated the boundary layer structure on smaller scales (less than 70 km) and over correspondingly shorter time-scales (a few hours) where conditions were more uniform. The results showed that continuous, small-scale turbulent mixing was generally confined to a layer only a few hundred metres deep, driven largely by the effects of surface friction. The measured stress and geostrophic departure were fairly closely balanced within this layer which was separated from overlying cloud layers and the lowest inversion by a considerable distance.

However, direct coupling between the mixed layer and the overlying atmosphere was often observed in the form of cumulus convection which, although intermittent and irregularly distributed on the scale of the measurements (less than 70 km), did appear to transport significant amounts of water vapour. The direct measurements therefore imply a considerable change in the structure of the transport mechanism at the top of the mixed layer.

This transport by cloud and the scales on which it is observed to occur provide the key to reconciling the apparently different results from the radiosonde and the direct measurements. The effects of mesoscale variability are implicitly included in the larger-scale budget results. Clearly, the similarly sized mesoscale eddies observed in the ocean could directly contribute to this variability through changes in the fluxes across the interface.

The aircraft were also able to make detailed measurements of the dynamics, cloud physics and radiation fields within stratiform cloud layers. The long- and short-wave components of the cloud-layer energy budget were measured and good agreement was obtained between the observations and several radiation schemes, in particular the cloud short-wave absorption. These cloud layers were often observed to be decoupled from the mixed layer adjacent to the surface although higher turbulence intensity levels were often found in cloud. Results such as these have enabled the importance of cloud-related mixing processes in the evolution of the boundary layer to be assessed and have recently led to a renewed interest in these phenomena.

Meteorological Research Flight

The Meteorological Research Flight (MRF) of the Meteorological Office is located at the Royal Aircraft Establishment (RAE), Farnborough. It now operates a single RAF aircraft, namely a Hercules C-130, the Canberra having been withdrawn in 1981. Flight crews are provided by the RAF but most of the aircraft maintenance is carried out by RAE personnel.

MRF is responsible for scientific instrumentation installed in the aircraft. The Hercules is extensively instrumented to carry out studies of the lower levels of the atmosphere having in addition to the more traditional sensors (for wind, temperature, humidity etc), radiometers, equipment for studying cloud structure, a drop-sonde system and an extensive chemical sampling capability. It is used as a research facility by several research Branches of the Meteorological Office (notably Boundary Layer and Cloud Physics) as well as by universities and other research groups. In addition, studies of some atmospheric processes, notably those concerned with radiative transfer and mountain waves, are carried out by scientists based at Farnborough as part of the establishment of MRF.

The instrumentation of MRF aircraft has always been subject to continual review as new requirements generated by evolving research interests have to be reconciled with the need to maintain existing instruments. Thus the past year has seen the first fibre optics line (needed to relay data from instruments mounted in the wing pod) installed in the port wing and planning started for installation of a multi-channel radiometer as well as the provision of a new nose probe and a replacement refractometer (used to detect high-frequency changes in water vapour). However the bulk of the effort, over and above that needed for routine maintenance, has been devoted to the design and development of new data recording systems based on microprocessors.

Before the Canberra aircraft was removed from service last year, it made a number of flights above and below cloud sheets with a multi-channel radiometer, banking the aircraft in order to study how the transmission and reflection of sunlight by clouds varied with angle. These measurements were made in a narrow spectral interval (1–2 μm) and when combined with information on cloud characteristics, especially on occasions when microphysical measurements were made concurrently within cloud by the Hercules, provide valuable insights into some of the radiative characteristics of layer clouds. It is already clear that within this spectral region the reflectivity of ice clouds can be distinguished from that of water clouds which generally contain smaller particles. A Monte Carlo multiple scattering model has been developed to see whether observations of scattering by thin cirrus clouds are consistent with current theories, notably their sensitivity to various assumptions about the characteristics of the ice particles of which these clouds consist. This work has indicated that the 'equivalent radius sphere' approximations are not adequate.

The presence of aerosol can significantly modify the radiative properties of clear air. In an attempt to extend our understanding of this, the Hercules aircraft has been making broad-band measurements of short-wave and long-wave flux divergence in cloud-free air with the aim of relating these observations to aerosol profiles. Several good case studies have been carried out and the measured fluxes are being compared with those inferred from aerosol data and a theoretical short-wave model. However, it will never be possible to determine all the relevant aerosol characteristics from an aircraft (though as far as is practicable this is being done; for example an integrating nephelometer is to be installed) so MRF is liaising with other groups who have an interest and a capability in aerosol monitoring in order that aircraft observations can be co-ordinated with more comprehensive data gathered at the surface.

When a stably stratified airstream encounters a mountain range the flow is disturbed, notably by the generation of wave trains and increased drag. There have been numerous investigations of disturbances associated with large orographic features such as the Rocky Mountains but far fewer concerning small mountain complexes such as those found in the UK. Thus over the past few years MRF aircraft—both Canberra and Hercules, sometimes in concert—have made a number of flights over mountainous regions of the UK to investigate wave characteristics of disturbed flow associated with wide areas of relatively small mountains. The aircraft can make quite detailed studies of the flow, including horizontal wavelengths, wave amplitudes, momentum fluxes etc. Analyses to date have revealed a strong dependence on upstream conditions as well as showing that the downward fluxes of momentum can be comparable with those normally only observed near the surface. Observations of wavelength and variations in wave amplitude with height from several flights have agreed well with the predictions of a simple two-dimensional linear model. On one occasion two lee-wave trains were identified, the shorter of which was strongly trapped and dominated changes in vertical wind velocity below 3 km, while the other longer wavelength was only apparent above 6 km.

For many years the Canberra aircraft made measurements of water vapour content of the lower stratosphere. Analysis of the most recent set of data covering the years 1977–80 has been completed. This shows that the gradual increase in humidity observed in this region during 1972–76 has continued. The raw data set includes seasonal data collected over the latitude range 45°N to 65°N which should prove invaluable in identifying sources and sinks of stratospheric water vapour needed to understand some of the underlying processes occurring in this part of the atmosphere.

Atmospheric chemistry

The abundance of certain trace chemical species in the atmosphere can influence the atmospheric circulation through their effect on the local radiation balance. Over the past few years there has been an increasing awareness of the problems which may be caused by artificial sources of various species, for example carbon dioxide from fossil fuel burning, chlorofluoromethanes from aerosol propellants and water vapour and oxides of nitrogen from stratospheric aircraft flights. (Such sources have recently been referred to in the literature as 'anthropogenic'.) There are fears that such species alter the atmospheric distribution of ozone, carbon dioxide and water vapour which may adversely affect the climate of the earth. Another area where the complex interaction between meteorology and chemistry has become apparent is the problem of 'acid rain'. This problem results from the fact that chemicals released close to ground level from power stations, chimneys etc., may travel as far as a thousand kilometres downwinp undergoing a complex series of reactions before being washed out of the atmosphere by rain or deposited on the surface by dry turbulent deposition. The deposition of these pollutant species may have an adverse effect on the flora and fauna of the region where they are deposited. Owing to the intricate nature of the interactions between different chemical species, which often depend on height, radiation and humidity, it is necessary to undertake complex calculations including the effects of atmospheric circulation if the influence of artificial sources is to be properly assessed. In addition, in order that long-term trends can be detected at an early stage, a program of monitoring certain key species is also necessary.

Measurements of the chemical composition of rainwater are made by the Laboratory of the Government Chemist which analyses samples of rainwater collected by the Meteorological Office in special rain-gauges at Eskdalemuir, Lerwick and Bracknell. Data from gauges which are always open and from gauges which are only open when rain is falling are compared to assess the contributions to the total surface deposit (on the funnel material) resulting from both dry and wet deposition. Data from Eskdalemuir are exchanged internationally as a contribution to the World Meteorological Organization (WMO) Background Air Pollution Monitoring Network. The samples are analysed for pH and for the concentrations of sulphate, nitrate, chloride, ammonium and various metallic ions. The Office has co-operated with other organizations in the United Kingdom which make similar measurements through representation on the Review Group on Acid Rain.

The routine measurement of the total amount of ozone in an atmospheric column at a number of sites forms part of the WMO sponsored ozone monitoring program. The Office undertakes measurements at Bracknell, Lerwick and St Helena and is also responsible for calibration and maintenance of instruments at Singapore and Mahé. The Singapore instrument was cross-calibrated in 1982 when the opportunity was also taken to make a number of modifications, developed at Bracknell, with the aim of simplifying operating and calibration procedures.

In addition to the routine monitoring programs, measurements of nitrogen dioxide in the stratosphere have been made on an occasional basis. The technique relies on measurements of absorption of solar radiation. A prototype of an instrument for small balloon-borne sampling of the stratosphere has been constructed and is now being tested.

Numerical models of varying complexity are being used to assess the important parts of the cycles of key chemical species. A one-dimensional model has been used to demonstrate that the diurnal variations in ozone concentration in the stratosphere, due to a range of photochemical reactions, are strongly height dependent. This height dependence sets limits on the depth of the atmosphere over which representative data may be obtained by remote sounding techniques. Predictions by the model are being compared with observations made elsewhere. A similar model has been used to investigate the diurnal variations of ozone in the mesosphere and it has been shown that rocket observations can only be explained when effects of atmospheric tides are included.

The full complexity of the chemical and dynamical interactions can only properly be investigated using a three-dimensional numerical model. Work is continuing on a project to examine the distribution of water vapour, ozone and potential vorticity derived from a general circulation model. Work on the fluxes of water vapour in the stratosphere and upper troposphere is now complete. It has been demonstrated that the cross-tropopause transport of water vapour is a significant part of the budget of water vapour at these levels. Calculations of the chemical evolution within parcels following trajectories in the stratosphere are now being carried out using typical three-dimensional trajectories derived from the numerical simulations of the atmospheric flow.

The results from the numerical experiments have demonstrated that it is necessary to make global-scale measurements of some trace species if their distribution is to be adequately described. Such measurements will be made from future satellites and the Office is represented on the scientific team for the Halogen Occultation Experiment due to be flown at the end of 1988 on the Upper Atmosphere Research Satellite (UARS). The Office also is involved with a theoretical investigation in its own right connected with UARS.

In the troposphere, numerous observations have been made using the gas chromatograph installed on the Hercules aircraft of the MRF. The equipment can take air samples and analyse them for a range of chemical species. Recent modifications have enabled the equipment to work successfully up to the operating ceiling of the Hercules. Several flights around the United Kingdom within the atmospheric boundary layer have been undertaken. The observations show the expected large peak concentrations of many pollutants downwind of industrial sources. It has also been demonstrated that there is a high correlation between regions of high chemical concentration and regions of high particulate concentration. A number of chemical sampling flights have also been undertaken in collaboration with the Central Electricity Research Laboratories, Leatherhead, to investigate the evolution of certain species in the lower atmosphere. It is apparent from the data that in some circumstances the effects of washout on chemical evolution in the presence of cloud or precipitation may be more important in determining chemical composition than the effects of turbulent diffusion and deposition.

Satellite meteorology

Data from the US polar-orbiting satellites have been analysed and it has been shown that good-quality temperature profiles can be obtained in the troposphere using data received directly at the station at Lasham. A small computer system has been ordered to provide temperature and humidity profiles for an area within 3000 km of Lasham on a routine basis. When the computer becomes operational, meteorologically useful information, both for forecasters and numerical models, will be available both earlier and with improved horizontal resolution, compared with existing arrangements through the Global Telecommunication System. The computer programs being developed were modified at short notice to provide temperature information over the South Atlantic during the Falklands crisis, albeit of reduced quality owing to the use of data from only the four microwave channels of the satellite's instrumentation.

The Stratospheric Sounding Units (SSU), provided for US polar-orbiting satellites by the Office, continued to provide exciting data. As a result of careful instrument calibrations it has been possible to use SSU data for a detailed study of solar tides in the stratosphere as well as the lunar tidal work reported last year and for the long-term monitoring of changes in global mean temperature. Data from the SSU confirm those from radiosondes which show a warming of the lower stratosphere, possibly connected with volcanic eruptions during the year; in addition the SSU data suggest that some cooling has occurred at higher levels in the equatorial zone.

Further work on the interpretation of satellite data has been directed towards making more use of high-resolution image data which are available in up to five spectral bands from the US polar-orbiting satellites. A method of distinguishing fog or low stratus from cloud, land or sea has been demonstrated.

The Office's proposal for an instrument to measure surface pressure, the Active Microwave Pressure Sounder (AMPS), was not accepted by the European Space Agency (ESA) for their Remote Sensing Satellite, ERS–1. Further case studies have been made to improve the assessment of the likely performance of AMPS, and measurements with ground-based radiometers have improved our understanding of the spectroscopy. Some numerical simulation work has been done to establish the feasibility of detecting the tropopause by scanning the earth's limb from a satellite.

Preliminary studies have been undertaken to determine what assistance might be given to the Rutherford Appleton Laboratory and the University of Oxford in the development and production of the Along Track Scanning Radiometer (ATSR), an instrument which is designed to provide accurate measurements of sea surface temperature. The ATSR has a place on ERS–1. Discussions have taken place with the National Environmental Satellite Service in the USA to determine the possibility of the Office's providing part of the proposed Advanced Microwave Sounding Unit. This instrument is expected to provide better profiles of temperature and humidity in cloudy conditions.

The Meteorological Office played a major part in inter-departmental discussions of a UK national remote sensing program in support of ERS–1. The Office's interest will be in exploiting observations of surface wind and state of sea which should be available from ERS–1. The Office also provided experts to assist ESA to define meteorological requirements for one of the on-board instruments and subsequent data handling for ERS–1.

Two SSUs provided by the Office have been in orbit through the year. That on NOAA–6, one of the US satellites currently in a polar orbit, has now performed excellently for 39 months compared with its design life of 24 months. The one on NOAA–7 is functional but the heights at which measurements of upper stratospheric temperature are made have changed slowly because of leaks in two of the pressure modulation cells. Comparisons between the instruments indicate that measurements are consistent to 0.2 K. Eight SSUs were built to flight standards, of which four have been launched, three successfully. A further one is being incorporated into a satellite which is scheduled for launch in February 1983 and the remaining three are held in storage at Bracknell where they are periodically checked and calibrated. Measures have been taken to reduce the cost of the transatlantic link used to receive data from the SSU and also to allow connection of the line directly to the Meteorological Office computer installation, COSMOS, rather than to a magnetic tape station.

The Meteorological Office contributes the UK's share of the operating costs of the European geostationary meteorological satellites. Meteosat-2, launched last year, has continued to function well apart from the data collection facility which has not been available since launch. Data collection is still handled by Meteosat–1 whose imaging radiometer became defunct in November 1979. Quantitative products derived from Meteosat–2 data (winds, sea surface temperatures, upper troposphere humidity and cloud-top heights) became increasingly available through the year and images were readily available except during March when problems were encountered with the camera's scanning mechanism.

Prospects for a future operational program of European geostationary meteorological satellites were significantly improved when the Federal Republic of Germany agreed to participate. Many meetings and discussions were held in the second half of the year with the aim of establishing an effective program to provide coverage from the mid 1980s to the mid 1990s.

The Short Period Weather Forecasting Pilot Project
The ability to observe and analyse cloud and precipitation patterns has been greatly improved by advances in radar and satellite imagery and new methods of processing, transmitting and displaying the data. These improvements are expected to lead to increased accuracy and detail in local forecasts of precipitation for periods of 0 to 6 hours ahead and in some cases up to 12 hours ahead. The Short Period Weather Forecasting Pilot Project which started at the Meteorological Office Radar Research Laboratory in Malvern in 1978 is aimed at developing the necessary observational and analysis facilities and optimizing their impact on the forecasting capability of the Meteorological Office.

The network of weather radars which has been in use since 1979 consists of radars at Camborne (Cornwall), Upavon (Wiltshire), Clee Hill (Shropshire) and Hameldon Hill (Lancashire). Qualitative coverage extends over a large part of England and Wales but London and eastern parts of England are not yet properly covered. Work will begin soon to establish another radar near London. During the past year software for the radar site computers has been restructured to make it more reliable and to enable it to be more easily maintained and modified. Methods of using telemetering rain-gauges to calibrate the radars were incorporated in the Clee and Hameldon Hill radars in 1981. Preliminary assessments indicate that these methods are producing an improvement in average accuracy but further work is needed to overcome the problem of sudden changes in calibration.

Rainfall data from individual radars are sent digitally at 15-minute intervals to a small number of forecasting offices and Water Authorities. The data are in the form of rainfall patterns and in some cases accumulations over predefined areas (subcatchments). In addition, data are sent routinely to the Meteorological Office Radar Research Laboratory at Malvern where a composite display is generated automatically within about 5 minutes of data time and retransmitted to a few of the main forecasting offices. The compositing software, like the software at the radar sites, has grown up over a period of time, and this too has been restructured to cope with anticipated developments, including the planned incorporation of data from weather radars in the Republic of Ireland, France and elsewhere. The rainfall data, whether from a single radar or from the entire network, can be displayed on a colour television monitor as a matrix of 5 km squares based on the National Grid.

In order to provide advance warning of rain-bearing systems approaching from over the sea and from other areas where radar cover is lacking, satellite cloud imagery is used. The main source of satellite data in the Pilot Project is the half-hourly imagery from the European geostationary satellite, Meteosat. Visible, infra-red and water vapour imagery are received digitally by means of a Primary Data User Station (PDUS) at Malvern. The resulting pictures are automatically remapped to a National Grid projection identical to that of the radar data and displayed within about 25 minutes of nominal data time on a colour television monitor with action-replay capability. The satellite cloud imagery available in this format is being evaluated for its own sake; however, procedures are also being developed to analyse the cloud data in terms of precipitation. There is no simple relationship between cloud imagery and surface rainfall and the approach to be adopted is likely to require some subjective interpretation by the meteorologist.

One of the characteristics of the rainfall fields derived from a radar network and from satellite imagery is that most of the sources of error are physical in nature rather than due to straightforward instrumental errors. Thus a knowledge of the general meteorological situation is needed in order to correct for them. This calls for the development of analysis procedures whereby the radar and satellite data can be compared with other forms of meteorological data. These procedures must be carried out quickly if the resulting analyses are to be available promptly enough to be useful, and to this end advanced man–computer interactive video display techniques are being pioneered. The interactive display system, which is being developed for the Meteorological Office by Logica Ltd and is known as FRONTIERS, will be undergoing initial trials during 1983.

In addition to its role in enabling the forecaster to analyse and control the quality of the rainfall information from radars and satellites, FRONTIERS is designed to enable simple extrapolation forecasts to be made for the period 0 to 6 hours ahead using computerized rain cell identification. Studies have been carried out into the forecastability of both frontal and convective precipitation. Analysis of errors indicates that the forecastability of convective rain by this simple means is limited by development and decay of the clouds. The accuracy deteriorates badly beyond an hour or two. In the case of frontal rain, however, useful accuracy is retained over longer periods and one of the main factors contributing to error has been shown to be the errors in the initial data rather than development and decay. Analysis and quality control of the initial data using the FRONTIERS display system is thus expected to provide the basis for the development of useful short-period rainfall forecasts over the next year or two.

Radar network and satellite data acquired as part of the Short Period Weather Forecasting Pilot Project are being archived for use in parallel studies of the structure and evolution of mesoscale weather systems. These studies are leading to the development of conceptual models which help the forecaster to understand and interpret the new forms of data. Some of the studies undertaken during 1982 have been concerned with the structure of fronts, the influence of topography on the distribution of showers, and the effects of orography on frontal precipitation. One particularly detailed case study using radar and satellite data was undertaken to reveal the nature of the airflow and precipitation mechanisms responsible for the major snowstorm of 8/9 January 1982 which gave 60 cm of snow over large parts of South Wales.

Geophysical fluid dynamics

The high degree of complexity of the atmosphere tends to obscure the fundamental factors that control large-scale atmospheric motions. The main work of the Geophysical Fluid Dynamics Laboratory is intended to explore basic dynamical processes in rotating fluids, of which the earth's atmosphere is but one example. Other natural fluid systems in which rotation plays a dominant role are the oceans, the liquid core of the earth (where the earth's magnetism originates) and the atmospheres of other planets.

Co-ordinated studies of dynamical processes in rotating fluids are carried out using several methods. These comprise (a) the detailed examination of flows in laboratory systems (see Plate VII), (b) computer simulations of these flows and (c) the mathematical analysis of a variety of related but simpler systems. The laboratory studies suggest new ideas and lines of theoretical research, while the combination of laboratory measurements and computer simulations provides amongst other things a unique opportunity to subject numerical models to tests of performance that are much more stringent than those possible in corresponding numerical work on atmospheric motions.

Many features of the large-scale atmospheric circulation can be reproduced in liquid filling a rotating annular tank, the inner and outer walls of which are maintained at different temperatures. The transfer of heat by the fluid between these walls simulates the transport of heat from the equatorial regions towards the poles by the wind systems. The laboratory studies show that several different regimes are possible. The flow may be axisymmetric, it may contain a 'jet stream' with regular wave-like perturbations or it may be highly irregular. Laboratory studies have established the external conditions under which such regimes are to be expected. 'Intransitive' behaviour of the system, where more than one equilibrium state can occur for the same external conditions, greatly complicates these studies and has implications for climatological investigations. The progression from axisymmetric through regular wave-like patterns to highly irregular patterns is now known to be typical of the behaviour of many dynamical systems and is the subject of a considerable amount of mathematical research in institutions around the world.

The results of several numerical simulations of annulus flows have now been compared with the corresponding laboratory measurements. The numerical model has such a fine resolution that the only sub-grid scale processes present are molecular viscosity and thermal conductivity and they can be represented precisely. The main features of the regular flows are found to be in good general agreement with observations, although certain details, which could be important in a model used for prediction, show appreciable discrepancies. These comparative studies have implications for attempts to model the more complex flows found in the atmosphere and to develop a soundly-based theory of atmospheric predictability, which is a major goal of the work.

There are two general types of regular flows found in laboratory systems, namely steady flows and periodically-varying flows ('vacillation'). After some considerable initial difficulties it has proved possible to reproduce certain examples of vacillation numerically and one recent simulation has provided a very clear example for dynamical analysis.

The occurrence of the regular waves regime in the annulus system is of major theoretical significance and has not yet been fully explained. The existence of such waves shows that non-linear processes can promote order rather than disorder in the flow and implies that theories of atmospheric predictability based on traditional turbulence concepts may be unduly pessimistic. Our experiments are providing considerable insight into the ordering influence of non-linearity.

The high-resolution pictures of the atmosphere of the planet Jupiter obtained by the Voyager 1 and 2 space probes confirm that the Great Red Spot and several dynamically-similar though smaller features are very stable eddies embedded in regions of highly-sheared flow. A new hypothesis as to the nature of the eddies has been introduced and is being tested by means of a program of laboratory and numerical studies of baroclinic eddies in systems subject to internal heating. Amongst the results thus obtained is a new interpretation of certain infra-red observations of Jupiter.

Wave motions of the same general type as those generated in the 'thermally driven' annulus can also be produced in a mechanically driven system consisting of two immiscible layers of fluid in a rotating tank with a lid which rotates faster or slower than the tank. In some respects the mechanically driven system roughly corresponds to the wind-driven circulation of the oceans. Latest work in this area is with numerical models and aims to elucidate the different dynamical balances in steady and vacillating flows.

In the field of geophysics theoretical studies have been carried out bearing on the origin of the earth's magnetic field and the structure and dynamics of the earth's interior. One of these concerns the likely behaviour of the geomagnetic field during a polarity reversal, for which provisional corroborative evidence has now been found in archaeomagnetic and palaeomagnetic data. A study of the meteorological contribution to observed changes in speed of rotation of the solid earth and movements of the earth's pole of rotation continued. This study has revealed several new features of the general circulation of the atmosphere which are now being investigated further.

Dynamical and Synoptic Research

Research related to numerical forecasting models

The largest element of the work under this heading has been the development and implementation of the new operational numerical weather forecasting system (comprising a data assimilation scheme and a numerical forecasting model) on the CYBER 205 computer. The research leading to the design of the new system was described in the Special Topic for the Directorate of Research in the Meteorological Office Annual Report for 1980. Work on establishing the new system on the CYBER 205 computer began in the latter part of 1981 and it was particularly fortunate that the development proceeded sufficiently rapidly for a complete, though as yet untuned, system to be ready just a few weeks before the outbreak of hostilities in the South Atlantic. Despite the fact that further development and improvement was considered necessary before the new data assimilation scheme and weather prediction model could satisfy all the Office's operational requirements, forecasts from the new system provided a valuable input to the meteorological advice given in support of the Task Force during its subsequent successful operations in South Georgia and the Falkland Islands (see page 15). The new system became fully operational in September.

The new data assimilation scheme has been designed to deal with a mixture of observing systems and types of observations so that the increasing number of observations made of the atmosphere using new techniques based on remote sensing, both from space and from the ground, and on automatic instrumentation can be used more effectively. Polar orbiting satellites, for example, are able to sense the radiation emitted by the atmosphere at infra-red wavelengths and this information is processed by computer to produce estimates of mean temperatures within layers of the atmosphere at different heights above the earth's surface. Temperature estimates made by this technique do not have the precision of those made by the more conventional radiosonde balloon ascents, but they provide a denser network of information enabling deductions to be made about horizontal temperature gradients that are extremely valuable over areas of the globe where observations from the conventional observational network are few and far between. The examination of sequences of photographs taken from geostationary satellites enables winds to be deduced by by following individual groups of clouds. Again, although the accuracy of individual winds derived in this way is not as good as that obtained from conventional radiosonde balloon techniques, the value of these data lies in their wide availability in data-sparse regions.

The basis of the new scheme is first to calculate weights to be assigned to the observations near each forecast model grid point using a procedure known as optimal interpolation. This is based on the theory that the ensuing interpolation from the observation points to the regularly spaced grid points of the forecast model should have a smaller statistically expected error than an interpolation using any other set of weights. The weights can then be expressed in terms of the expected errors of the observations and of the correlations between errors of neighbouring observations together with similar quantities for the forecast model. In this way the differing accuracies of various types of observations can be accommodated as well as the effects due to their uneven distribution. Forcing terms are then added to the equations of the forecast model that are proportional to the weighted averages of the departures of the forecast values from the observed values. As the equations for the forecast model are integrated forwards in time over a 6-hour period, the forecast gradually approaches the observed state of the atmosphere. The physical constraints implied in the equations of motion allow variables to adjust towards dynamical consistency. The computation involved in the analysis scheme does not naturally lend itself to vectorization on the CYBER 205 computer. Consequently considerable effort was needed in order to organize the computation to use as many vector manipulations as possible. The first version of the program was written without using the vector facility of the computer and the scheme took about 60 minutes on the CYBER 205 for each analysis. Later, when a substantial amount of vectorization was achieved, the time was reduced to about 10 minutes. Further savings are likely when 32-bit arithmetic is used throughout the computation.

Quasi-operational trials of the scheme began in the last quarter of 1981 and several modifications have been made since then to improve the quality of the analyses. One of the problems in deciding which features of the system should be changed in order to correct an observed defect has been the difficulty in distinguishing between inadequacies of the data assimilation system itself and faults in the forecasting model used for assimilating the data. An example of this was the high temperatures found in the analyses in the tropical stratosphere. This was traced to an error in the specification of latent heat release in the model itself rather than any fault inherent in the assimilation system. In order to track down the source of problems, each shortcoming has had to be carefully and methodically investigated and this has been greatly aided by having staff involved in the scientific development of the system who are also involved in the daily monitoring of the quality of the new analyses in the Central Forecasting Office. One aspect of the analyses that has been consistently better than in the old operational scheme has been the upper-wind analyses. They have shown sharper and better delineated jet streams, more accurate analyses of jet core speeds and closer fitting of aircraft observations.

An aspect of the scheme that has caused particular difficulty is the analysis of pressure observations, in particular at the surface. Because there may be inconsistencies in the relation between the analyses of the surface pressure and wind observations, a modification was introduced that created forcing terms for wind components that were geostrophically related to the observational forcing of the pressure fields. Similar hydrostatically related forcing of the temperatures was also applied. The effect of these was to tie together the wind and pressure field more effectively and the difficulties in assimilating pressure data were appreciably reduced. Other options have been added to the program and a series of tests is being undertaken to assess which combination of features produces the best results. Facilities have been provided to perform multi-variate analyses (that is to allow observations of one atmospheric variable to influence the interpolated value of another directly) and to calculate the observational forcing terms on a coarser mesh than that of the forecast model grid. There appear to be no harmful effects arising when the coarser mesh has a resolution of twice the grid-length of the model but there is a substantial saving in computing time that makes the modification a desirable one to introduce. Another change that has had a beneficial effect on the quality of the analyses is the increase in the radius from 410 km to 580 km of the area surrounding each grid point within which observations are permitted to influence the model variables. A facility has also been included that allows different forcing rates to be applied for different atmospheric variables. The first attempt to use this was to reduce the rate that wind data were assimilated to 30 per cent of the mass data assimilation rate. This had the beneficial effect of reducing roughness caused by fitting satellite wind observations too closely but it made the jet stream analyses worse because the upper-air wind observations were fitted less well. The forcing of the forecast towards the observations in the assimilation process gives rise to roughnesses that propagate through the model atmosphere as gravity waves. In order to control these, damping terms are applied to the divergence field. Later it was found that the most serious oscillations were due to the fastest moving waves—the external gravity waves. These could be controlled by damping only the vertically integrated divergences rather than the divergences at every level, a procedure that was computationally less demanding. Another modification that was introduced to save computer time was to evaluate the forcing terms due to the observations on a quasi-homogeneous grid near the poles (where the forecast tendencies are in any case filtered in the zonal direction by removing high wave-number components) and to interpolate them to the model grid points. No degradation in the analysis quality was noticed but there was a reduction in computing time of about 15 per cent.

Two quality control steps have been inserted prior to data being used in the analysis and assimilation scheme. The first compares the observations with a 6-hour forecast from a previous analysis. Observations which depart by more than a designated amount are flagged as suspect. The second quality control step compares observations with their neighbours. Observations flagged during the first step are re-checked in the second stage but are not used to check their neighbours. The criteria for rejection in the two quality control steps depend on the expected errors of the observations and on the expected errors of the forecasts. Early experimentation with the severities of the rejection criteria indicated that the most satisfactory results could be obtained if the first check was appreciably more stringent than the second. More recent experience suggests that this is not the whole answer and a more elaborate quality control scheme may be necessary. The weights calculated for the optimal interpolation also depend on the expected errors, and adjustments to these have been made on several occasions throughout the operational testing period to improve the resulting analyses. For example the assumed errors for high-level satellite temperature observations and of radiosonde wind observations have been reduced, implying that their influence on the resulting analysis is increased. The expected errors of the forecast are now permitted to be geographically dependent, varying between land and sea and tropical and extra-tropical latitudes as well as with height. Assumed forecast wind and mass errors are now linked geostrophically.

Development of the new 15-level numerical forecasting model has been going on in parallel with that of the data assimilation scheme. The model has a horizontal resolution of $1\frac{1}{2}^{\circ} \times 1\frac{7}{8}^{\circ}$ on a latitude–longitude grid and was first implemented over the region of the earth north of 30°S. A large effort has gone into ensuring that the programs run efficiently on the CYBER 205 computer making full use of its special features. This has meant arranging the data in the store of the computer so that computations can proceed over the entire horizontal array of grid points in a sequence of single vector instructions. It has been possible to organize the program so that it resides entirely inside the main store of the computer thereby eliminating temporary reads and writes to backing store on discs during the course of the computation. As a consequence the program takes only $2\frac{1}{2}$ minutes to perform each day of the forecast. It has also been necessary to develop a second version of the program capable of forecasting over the whole globe for use by the data assimilation scheme. This has an identical physical formulation but the data organization within the program uses appreciably less of the main store so that space is made available for the additional computation involved in the data assimilation. Although the transfers of data to and from disc that are nesessary in this version take place concurrently with the computation, the shorter vector lengths involved mean that the program takes about 12 minutes for a one-day forecast. During the year, however, further work on the forecast model program has led to the development of a version that will permit the calculation and data for an entire global forecast to be retained within the main store of the computer enabling a one-day forecast to be performed in 3.7 minutes. Although this version cannot be used for the data assimilation (because there is insufficient space left for the extra computations involved), it does mean that global forecasts can be made in very little more time than had previously been needed for doing forecasts over the region north of 30°S.

In order to avoid the necessity of using very short time steps to maintain computational stability near the north pole (where the meridians converge), the tendencies are smoothed by filtering out high zonal wave-number components. A 'Fast Fourier Transform' routine has been designed to work very efficiently on the CYBER 205 computer and this has been used in the section of the forecast program that performs the filtering operation. (A number of research institutes in the USA that have also installed CYBER 205 computers have shown interest in acquiring this routine, which is appreciably faster than the version supplied by Control Data Corporation, and it is now used in several other Branches within the Office.)

The program of trials of the new model also showed up a number of defects in the formulation which have led to the design of improvements. One of these was associated with diffusion in the neighbourhood of mountains. The original version of the model diffused potential temperature, momentum and humidity mixing ratio along the terrain following 'sigma' coordinate surfaces of the model. In places where the slope of the underlying orography was steep, this form of diffusion spuriously linked fluxes in the vertical with those in the horizontal. A change in the formulation to ensure that only terms involving diffusion along constant pressure surfaces were calculated improved the forecast fields in mountainous areas. Another characteristic error of early forecasts with the model was that depressions tended to become much too intense. This erroneous behaviour was traced to parts of the convection and boundary layer parametrizations where very shallow layers had been used to permit a more detailed description of the atmospheric structure near the ground. A change in the formulation to permit the lowest two layers to be combined in situations where large vertical fluxes were required led to more realistic heating and friction in the model and to improved forecasts of the depths of depressions. It has also been found that the results are sensitive to the precise formulation of the convection scheme. Adjustments had to be made to some of the constants involved in order to prevent excessive cooling in mid-troposphere. Work is well advanced on the introduction of a fully interactive radiation scheme that uses predicted humidities and inferred cloud amounts to calculate the reflection, absorption and emission of solar and infra-red radiation. At present, climatological distributions of cloud and humidity are used in the radiation calculations.

Each week, as part of the process of identifying shortcomings in the model, its forecasts were compared with others, including those of the 10-level model which until September 1982 was the Office's operational model. These detailed comparisons were discontinued when the new model became operational since it had become clear that its forecasts were, on the whole, at least as accurate as the best of those produced elsewhere and consistently more accurate than the 10-level model predictions. Assessments of performance are now made by the medium-range forecasters in the Central Forecasting Office. Detailed evaluations are now made each week of the accuracy of short-period rainfall forecasts and of tropical forecasts. As well as examining the behaviour of the model in regular weekly 5-day forecasts, its performance has been tested in a 50-day integration using the same initial data as an integration with the 11-level general circulation model, the object being to identify the more slowly growing systematic errors. Several features were similar in both models, but detailed examination of the results is still being carried out. Co-operative experiments to test the model and data assimilation scheme are also under way; analyses and models from different centres are interchanged and forecasts with different analyses and models compared. One of the models used in these experiments has been the operational medium-range forecasting model of the European Centre for Medium Range Weather Forecasts (ECMWF) whose products are available later than those of the operational system.

One of the co-operative experiments in which the Office played a major part was organized by the Global Atmospheric Research Program (GARP) Working Group on Numerical Experimentation (WGNE). This was an international experiment whereby a number of research centres around the world were supplied with the same set of initial data from which to run their numerical forecast models. Two cases were distributed, one for January and one for June, both of which coincided with special observing periods of the 1979 GARP global observing experiment, when a particularly dense set of observations was made throughout the world. The Office was responsible for assessing the results from all the models for the January case (assessment of the June case was done in the USA). Six national centres took part in the intercomparison project, the European Centre for Medium Range Weather Forecasts, the US National Meteorological Center, the Laboratoire de Météorologie Dynamique, the Deutscher Wetterdienst, the Japanese Meteorological Agency and the Meteorological Office. A total of ten different models were compared. Detailed assessment is still going on but preliminary results indicate that all models showed considerable skill out to 7 days as measured by root-mean-square error statistics. When examining the predicted synoptic evolutions one of the most interesting aspects was the similarity of the nature of the model errors, despite the variety of the model formulations. This suggests, perhaps, that the initial data may have been providing one of the main sources of error. For example, at day 1, although the evolution at 500 mb over the North Atlantic was generally handled correctly, all the models mishandled the disruption of a trough over the USA. Similar common behaviour was observed for later periods in the forecasts.

A limited area fine-mesh forecasting model has been developed in addition to the global model. It has the same physical formulation as the global model but half the grid-length (i.e. a grid length of about 75 km) and only covers an area consisting of the North Atlantic and Western Europe. It is used in the Central Forecasting Office to provide guidance as soon as possible after observation times and to predict details of the weather, in particular the rainfall, in the neighbourhood of the British Isles for periods up to 36 hours ahead. When the model was first implemented, the rates of change at the lateral boundaries of the various atmospheric variables were specified from the coarser mesh global model so that weather systems were able to pass into and out of the limited forecast region. This worked satisfactorily in the early tests but when the model was implemented operationally it was found that large spurious surface pressure changes were occurring in the limited-area forecasts. The cause was eventually traced to the treatment of the lateral boundaries. Because, operationally, the global model is run later than the fine-mesh model (to allow time for observations from distant parts of the globe to be received) the lateral boundary tendencies were taken from a global forecast starting 12 hours earlier and not from a current analysis as is required for consistency. This procedure led to subsequent unrealistic pressure changes. The problem has been alleviated by using the global forecast to provide values of the variables on the lateral boundaries rather than values of the tendencies. Investigation of this feature of the model is continuing.

Other aspects of the fine-mesh forecasts are also being given special attention. A method of allowing for the evaporation of rain falling through relatively dry air has been introduced; it prevents excessive amounts of rainfall being predicted in some areas. Initial humidity analyses, which can be expected to have an important influence on the amounts of predicted rainfall, are being closely examined and methods are being devised to improve their quality.

Work is also going ahead on the development of a very fine-mesh 'mesoscale' model. It has a horizontal grid length of only 10 km and is intended as part of a very short-range (12–24 hours) local weather forecasting system to provide more detailed forecasts for the British Isles. It is planned to be ready for operational testing in the mid 1980s. Considerable effort has been put into reprogramming the model to run on the CYBER 205 computer. This has been done using standard FORTRAN but with as much vector operation as possible. The computer code is consequently easy to understand and modify. It does not make use of all the facilities of the CYBER 205 that are exploited by the new forecast model and the new data assimilation scheme but, nevertheless, the program runs nearly 15 times faster than it did on the IBM 360/195 computer. When introduced operationally, the code will be rewritten to perform even more efficiently. Development of techniques for the initial data analysis for the mesoscale forecast model continued during the year. A simple and efficient analysis technique based on the use of recursive filters has been completed. Its capabilities have been demonstrated in a general computer program which takes observations from the operational data bank and produces a contour chart of the analysed field. The scheme has been used successfully to analyse several of the parameters reported by surface observing stations. In the most extensive test, analyses have been produced of stratiform cloud amount, cloud base and precipitation, and they have been interpreted in terms of a three-dimensional cloud water distribution. A preliminary experiment to test the response of the mesoscale model to assimilation of cloud information produced encouraging results. Work on a variational initialization scheme has also continued but difficulties have been encountered with convergence in the final section. Programs have now been written to obtain initial conditions for the mesoscale model by interpolation from the 15-level operational fine-mesh model. The interpolated values give a preliminary estimate for a mesoscale analysis, in which the recursive filtering technique determines as much about the mesoscale structure of the atmosphere as can be deduced from the observations. Ideally, the intervention of a human forecaster could provide a valuable input during this process by interpreting satellite pictures and radar rainfall observations in a suitable way. Accordingly, a detailed study has been made of the operational requirement for a suitable interactive graphics terminal. It appears that, since the features needed for such equipment are similar to the requirements of other possible users, a facility shared with other Branches within the Office would be adequate for the research phase of the development of intervention techniques.

The new and more general boundary-layer turbulence parametrization scheme for the model has been further developed. It is based on the so-called 1½-order closure of the hierarchy of equations for turbulence quantities. The only additional prognostic equation is that for the turbulent energy. Terms representing creation by wind shear, creation or destruction by buoyancy, dissipation and transport of the turbulent energy by the eddies are all included. Particular care has been taken with the last term as it is well known that the turbulent energy flux can be counter-gradient in convective conditions. The scheme has been tested in one-dimensional form on detailed boundary-layer observations. The general character of the variation through the day was well simulated. However, entrainment at the inversion capping the mixed layer seemed to be insufficiently large to allow the mixed layer to grow to the observed height. The scheme has now been programmed for the fully three-dimensional mesoscale model for further testing. A weak instability has been discovered in the scheme and work is in progress on devising a method of curing it. Moisture and rainfall processes are now included in the model. At first a simple technique similar to that adopted for the new forecast model was included. Later the scheme was made more realistic by including the prediction of cloud water, allowing for conversion of the cloud droplets either to raindrops or back into water vapour by evaporation. Realistic results have been obtained in a single case study. A survey has been made of methods of parametrizing cumulus convection. One of the difficulties encountered is that most methods assume that interchanges of air parcels occur throughout the depth of the convection in one time step. In the mesoscale model, the time step (about one minute) is short compared with the life time of a deep convective system (an hour or so) and consequently such techniques are unsatisfactory. However, a full representation of the physical and dynamical process within convective clouds is not possible because the horizontal resolution (10 km) is inadequate. A proposal for a parametrization that takes account of the relatively long time scales involved has been made and is being tried out.

There are a number of fundamental mathematical problems associated with the representation in finite difference models of small-scale phenomena which may appear, relative to the coarse grid of the numerical forecast model, as discontinuities. Such features can arise spontaneously within an otherwise smooth and continuous flow. Work has started on checking that the finite difference schemes currently used in the various forecast models converge to the correct physical solution in the presence of discontinuities such as fronts, jet stream boundaries, squall lines, etc. It is known from other branches of computational fluid dynamics that it is possible for incorrect solutions to be obtained under these conditions. The rates of convergence are also being studied, to get a better estimate of the resolution requirements for modelling these features. It will be very important to handle them correctly if significant progress is to be made in forecasting detailed weather conditions over the British Isles and elsewhere. A simple example containing some of the features to be studied is that of hydraulic jumps in a rotating system. These are discontinuous solutions of the shallow water equations which arise within a few hours if the Rossby number derived from the initial data is of order unity. They have been proposed as explanations of squall lines and some mountain winds. It has been found that the steady solution of the one-dimensional shallow water equations for flow over an isolated ridge is correctly given by finite difference methods in flux form, even in the presence of hydraulic jumps. However, there is some doubt whether the transient response is correct since the results disagree with published results for the same finite difference scheme. Another important aspect that is under study is the modelling of a front forced by a deformation field. This continues the work of Hoskins and Bretherton who showed that a discontinuity can propagate from the boundaries into the rest of the atmosphere. However, the upper and lower fronts cannot meet and the front remains split. A standard finite difference model does not appear to converge to the correct solution. The overall width of the frontal zone is correct but the variation of shape and strength with height is not. The correct solution is given by a model that solves the semi-geostrophic equations directly. An examination is also going on into whether finite difference forecast models correctly predict the nature of three-dimensional turbulence. Several observational studies have suggested that intermittent rather than isotropic turbulence is typical in the atmosphere. It has been proposed that this is associated with the concentration of the vorticity in small regions followed by a 'blow-up' of the solution to the inviscid equations. If this is correct, a finite difference model with artificial viscosity may not give the correct solution. Substantial evidence has been accumulated to support the idea of such a blow-up of the three-dimensional incompressible Euler equations in finite time. It is very difficult to obtain reproducible results because of their high sensitivity to the initial data. Work is proceeding on generating a set of results starting from smooth data to provide a convincing demonstration of the collapse in length scale that is believed to occur. Two Lagrangian numerical methods are being used in the study.

Synoptic climatology

The study of the behaviour of the atmosphere on time-scales of 10 days or more, and the development of improved methods of long range forecasting are closely linked and are the research interests of the Synoptic Climatology Branch.

Extensive archives are maintained of data from climatological stations throughout the world and new data are added continually, after careful control of their quality. Many gaps exist in past records and reliable information to fill them is sought, often in consultation with other meteorological services and institutions. Particular attention has been given this year to improving a daily temperature series for central England from 1755 which is being used in a study of 'spells' of persistent weather in the United Kingdom.

A world-wide network of upper-air soundings began to operate in 1948 but all the available compilations of results contain many errors and uncertainties, sufficient to confuse or obscure any small changes in climate that may have taken place. A reliable data set for the northern hemisphere has been created by requesting mean monthly upper-air data from the countries of origin for 150 selected stations, together with supplementary information such as the instruments used and the launching sites. Monthly or daily data from over 120 of these stations have been received and subjected to quality control. The data are particularly valuable for investigations involving tropical regions, which are not covered by the daily grid-point data sets archived from the surface and upper air analyses produced by the Central Forecasting Office. They have produced evidence, backed up by satellite radiance observations, for a warming of the tropical lower stratosphere after March 1982 when the volcano El Chichon in southern Mexico erupted. The station data proved adequate to show the vertical and horizontal extent of the warming and its changes with time, and it is concluded that the warming was the result of the combined effects of the eruption and of the quasi-biennial oscillation of the tropical stratosphere. The station data are also being used to extend earlier work on the quasi-biennial oscillation itself and its effect on extra-tropical circulations currently hypothesized as being linked through observed variations in the static stability of the tropical upper troposphere.

The archiving of the important relevant data provided by polar-orbiting and geostationary satellites has reached the stage where charts of total cloud cover, averaged over 15 days, are available for consideration in long-range forecasting, and comparisons of data from different satellites are in hand. The data are to be used to provide world-wide estimates of cloud cover and other parameters, which define the albedo and the radiation balance of the earth, for use in numerical modelling experiments.

The global set of sea surface temperatures based on ship observations going back to 1854 is being improved by the addition of recent data and also extra data becoming available for many of the earlier years, and the set is being used as the basis of studies (partly under the contract with the Department of the Environment) of the association between anomalies of sea surface temperature and atmospheric circulation patterns, and of long-term trends. A preliminary study of the variation of decadal mean values of sea surface temperature has shown some large regional variations during the last century; for instance, in the tropical North Atlantic Ocean the sea surface temperature increased by at least 1 °C between 1910 and 1955 over a wide area in many months of the year, but in sub-arctic latitudes there was a cooling: this confirms previously suspected variations. Larger variations in the north-west Pacific Ocean remain to be confirmed. Parallel variations in the northern hemisphere atmospheric circulation patterns are also being studied. Despite the problems of data quality it also appears that there have been real long-term trends superimposed on the interannual variability in the globally averaged sea surface temperature: the ocean surface may have warmed on average by about 0.5 °C in all seasons from about 1910 to about 1955 with a subsequent cooling of perhaps 0.2 °C. A second archive of sea surface temperatures is being compiled from daily data which blend satellite, ship and buoy observations and which are received from the USA over the Global Telecommunication Network. This is particularly useful in preparing long-range forecasts and has proved invaluable for monitoring the major fluctuation in sea surface temperature in the tropical Pacific during 1982. This type of fluctuation occurs at irregular intervals of a few years and affects the atmospheric flow principally in the Pacific but to a lesser extent in the Atlantic sector also.

In addition to directly observed data, archives of analysed data are also maintained in the form of the objectively analysed grid-point data produced by the Central Forecasting Office and data on derived quantities such as the mean westerly flow and horizontal and vertical fluxes of heat and momentum. The Central Forecasting Office analysis procedure has changed radically since the introduction of the new operational forecasting model this year; comparisons have had to be made to identify important systematic differences between analyses produced by the two systems.

Research related to long-range forecasting

The experimental long-range forecasts have preserved continuity with those issued to the public until December 1980, but the procedures have been streamlined and automated as much as possible. The forecasts are prepared by a small group of scientists who attempt to combine the results of a number of statistical techniques with their own insights based on extensive experience of atmospheric behaviour. A new method of multivariate analysis under development for several years has become the most prominent forecasting procedure. It uses a variety of statistical approaches to construct forecasts of surface circulation patterns from several types of data including surface pressure, air temperature and sea temperature from much of the northern hemisphere; several of the older statistical methods are effectively incorporated in this more general technique. Tests of the multivariate method on independent data show that the method has some predictive ability and have also indicated ways in which the method may be developed in the future.

Information from medium-range numerical forecasts (available to about 6 days ahead) is also incorporated in the first few days of the forecast. Results from longer-period numerical forecasts are often taken into consideration too, though it is recognized that they do not provide reliable guidance at present.

A prime function of the long-range forecasting experiment is to focus attention on the many practical problems that have to be solved if regular monthly forecasts are to be produced in a form which maximizes the (inevitably limited) information available for the benefit of customers. For example, there is the problem of amalgamating the variety of indications given by several different forecasting techniques into one coherent forecast; also it is not easy to transform a forecast of a mean circulation pattern into, for instance, a surface temperature forecast, nor is it obvious that a monthly mean surface temperature is the best parameter to forecast when viewed in the light of the characteristic lengths of spells of temperature above or below average. Because of this the monthly forecasts are now constructed from two half-monthly forecasts which are often in marked contrast to each other. The experimental forecasts are sent by telex to a limited selection of commercial users in order to maintain contact with users' views and requirements. The forecasts have been carefully assessed for their accuracy.

Dynamical methods of forecasting, using large computers, have been very successful for forecasts a few days ahead but cannot be used in the same way on the monthly time-scale. The numerical forecasts may contain useful information on long-term behaviour of the atmosphere but this is usually swamped by short-term fluctuations and by errors associated with the model or with imperfect specification of the initial conditions. Careful study of the behaviour of the models and of their response to various types of perturbation is needed if they are to be used effectively in monthly forecasting. The use of a hemispheric version of a 5-layer general circulation model in long-range forecasting and the study of particular characteristics of its behaviour on the monthly time-scale has continued. Experiments have shown that, for this particular model, daily forecasts started from analyses for consecutive days on average become effectively independent after about 12 days. On most occasions, individual forecasts have by this stage lost all skill. Attention has therefore been concentrated on ensembles of integrations made from similar initial conditions such as consecutive daily analyses; when there is agreement between the individual members of the ensemble there is cause to place greater reliance on the forecast. However the ensemble must be compared carefully with the normal behaviour of the model (its 'climatology') before the forecast 'signal' can be defined. The model's climatology can be derived from the integrations performed over the last three years, and programs are being developed to enable the comparison with the forecasts to be carried out.

Work elsewhere has shown that dynamical models have more skill in forecasting fields from which the fast-moving short-wave features, such as mobile depressions, have been removed. The short waves need to be retained in the time integrations themselves for although the forecasts of their movement and development will be incorrect after the first few days, they make an essential contribution to the non-linear interactions in the atmosphere: the fluxes of heat, momentum and other physical properties, together with the external forcing such as surface heating have a profound effect on the behaviour of the larger features of the atmospheric circulation. Thus the altering of circulation features on different time- and space-scales and the combining of ensembles of forecasts form part of the methodology for determining which aspects of the atmospheric circulation are predictable and under what circumstances.

The 5-level model's economy in running and the quality of its general circulation simulations have made it a suitable vehicle for gaining initial experience in how dynamical methods can be introduced into long-range forecasting but it is not good enough to use operationally. The increased computing power provided by the CYBER 205 computer and the new regular operational global analyses make it feasible to perform long-range forecast experiments with a more highly resolved global model that will not have some of the known deficiencies of the 5-level model. Long-range forecasting combines the requirements of normal operational forecasting models which need to be able to integrate forward from real atmospheric conditions with high accuracy, and of general circulation models which have to be capable of reproducing the climatological features of the atmosphere in long integrations. A model for long-range forecasting will be created from those already available or being developed for these separate purposes. Tests have already been carried out to evaluate the new operational model in this role. A version, with rather coarser resolution which requires one minute of computation for each day of a global forecast run, has been used to provide month-long integrations such as would be required in producing long-range forecasts by dynamical methods. The 11-layer general circulation model has been used in a similar way so that the results can be compared. Results are being assessed with a view to deciding on the most appropriate version for future experiments.

A version of the general circulation model is already being used to study the influence of tropical east Pacific sea surface temperature anomalies. This region has been chosen for the initial experiment because tropical sea surface temperatures are believed to have more influence on the atmospheric circulation than those in other areas and in this particular part of the tropics the anomalies are largest both in extent and magnitude. Such anomalies are generally thought to be a crucial factor in the global-scale phenomenon known as the Southern Oscillation, which has been the subject of much recent research and thus a background exists against which the model's response to the anomaly can be assessed.

General circulation of the atmosphere

Research aimed at increasing our understanding of the general circulation of the atmosphere and our ability to reproduce it in computer simulations is an essential requisite both for improvements in long-range forecasting and for investigations of climatic change. Such research has been continued during the year through development and use of numerical simulation models of the global atmosphere and through complementary studies of observational data.

The observational data set collected during the First GARP Global Experiment (FGGE) is the most comprehensive yet available for research on the general circulation. The sequences of analyses produced from these observations have been used to calculate general circulation statistics, such as temporal and zonal averages and variances, and also quantities of special dynamical interest such as conversions between kinetic and available potential energy, components in the angular momentum balance and large-scale horizontal divergencies. Time filters have been used to study the contributions of different frequency bands to some of the general circulation statistics. For example the variances of band-pass filtered time series of geopotential height fields have been used to examine atmospheric variability on time scales in the range 2–6 days. Maxima in the patterns of such variances occur particularly along depression tracks, and this offers a useful technique for comparing numerical simulations with analyses. Through such comparisons, shortcomings in the simulations may be identified and clarified, and research to discover the causes of the shortcomings may be initiated.

Where possible, statistics and other derived quantities calculated from analyses made using different techniques have been compared in order to assess reliability. For example, two separate analyses of FGGE observations have been used in a study of the accuracy with which the divergence of the vertically integrated horizontal energy flux in the atmosphere can be calculated. As well as its intrinsic interest for general circulation research, this study permits an assessment of the feasibility of deriving the vertical energy flux at the ocean surface as a residual of horizontal fluxes within the atmosphere and the net radiative flux at the top of the atmosphere (available from satellite measurements). Such derivations of surface fluxes are part of a proposed international experiment to investigate the energy budget of the oceans.

The main emphasis in research on numerical simulation of the atmospheric general circulation this year has been on the development and use of a general circulation model for the CYBER 205. This model will subsequently be used in multi-annual integrations coupled with models of the oceans and sea-ice to simulate and to improve understanding of climate and climatic change. The model has 11 layers and a regular latitude–longitude mesh. In most experiments so far a 2° latitude by 3° longitude mesh has been used with January or July lower boundary conditions, but a $2\frac{1}{2}° \times 3\frac{3}{4}°$ mesh is also now available. Notice that the spatial resolution to be used in the general circulation model is coarser than that of the 15-layer operational forecast model. This is necessary to avoid prohibitive computing times for long integrations and to allow more storage space for the wide range of diagnostic information needed from simulations of the general circulation. The diagnostic and output programs have been adapted so that they can be used with the different mesh sizes. A general purpose interpolation program has also been produced to enable initial data sets to be obtained from data on a different mesh-size or from data on the irregular mesh in use on the IBM 360/195 or from the new forecast model. To allow long integrations with a minimum of manual intervention, it has been arranged that calculation of diagnostics, storage of results on magnetic tape and restarting from an appropriate point in an integration are all handled automatically, and documentation of the progress of each integration is also provided. Work continues on speeding-up the model both by optimized methods of computation and also by changing the accuracy of the calculations from 64-bit to 32-bit arithmetic.

A seasonally varying integration of a previous version of the 11-layer model has been completed after over 500 simulated days. Several aspects of the integration have been studied in detail, including the response of the primary variables to the seasonal forcing and the simulated radiation budget. The integration has highlighted some of the shortcomings of the model and the version being developed on the CYBER 205 computer has been used in conducting experiments to understand them and develop improvements. It has been shown, for example, that the temperature and humidity structure and rainfall distribution at low latitudes are very sensitive to the assumptions made in the penetrative convection scheme on the extent to which convective precipitation is evaporated as it falls. Atmospheric temperatures also fall steadily during integrations from real initial data, as the model cools towards an equilibrium state which is a few degrees colder than that observed. This feature is shared by many general circulation models and experiments show that it can be reduced considerably, especially in the stratosphere, by a different treatment of the subgrid-scale diffusion of temperature. A similar improvement, rather larger in the lower troposphere, can be obtained with the multipoint filter discussed in last year's Report. At present the diffusive treatment of grid-scale roughness is being retained because it is difficult to find an approach based on the filter which both conserves mass and maintains a smooth sea level pressure field, and because the model produces too many very deep depressions with the filter. The dependence of density on moisture content as well as temperature has been incorporated in the model; this can affect the pressure gradients and vertical circulation in the tropics particularly where large moisture gradients exist, as between the dry air over the Sahara and moist air over equatorial Africa.

Following the experiments reported last year on the sensitivity to large-scale variations in surface reflectivity and soil moisture content, numerical experiments have been carried out with a more realistic geographical distribution of surface reflectivity. These experiments are being performed in co-operation with the Department of Geography of the University of Liverpool. The purpose is to examine the sensitivity of the model to the geographical variation of land surface quantities such as reflectivity, soil properties, hydrology and surface roughness and to suggest areas where the formulations may be improved. In a related project, the ability of the model to simulate the surface and near-surface climate is being examined in detail over the European area as part of the EEC European Climate Programme. The model tends to generate excessive westerly flow over the area in winter and in an effort to understand this the simulated depression tracks are being compared with those observed.

Preparatory work has been completed for running the $2\frac{1}{2}° \times 3\frac{3}{4}°$ mesh version of the model in annual-cycle mode. Data sets have been prepared of climatological sea surface temperatures and sea ice for 5-day periods and of seasonally-varying zonally-averaged cloud and ozone amounts. Special attention has been given in preparing the surface data sets to the specification of coastlines to avoid distortions of the ocean currents when the atmospheric model is coupled with an ocean model.

Since the Asian summer monsoon is a very significant component of the global circulation of the atmosphere, particular attention has been given to this feature in observational studies and numerical simulations. General circulation model integrations with seasonally varying boundary conditions have simulated the general character of the monsoon onset quite well (although it is not yet known if the observed interannual variability of the onset can be reproduced in such integrations). Medium-range forecasts with the same model were not successful, however, in predicting the timing of the onset and the reasons for this are being investigated.

Research on the global climate

Extension of general circulation models to include representations of the oceans and of sea ice is necessary for any definitive studies of climatic change that may ultimately be possible. When sufficiently realistic simulations can be obtained with such coupled ocean–atmosphere models they will be used for experiments to investigate possible mechanisms of climate change, such as the increase in atmospheric carbon dioxide. Pending the availability of coupled models useful insight into this problem has been obtained using atmospheric models with prescribed changes in sea surface temperature. Studies of this kind are described in this year's Special Topic on carbon dioxide and climate.

An important feature in some of the possible mechanisms of climate change is a change in sea-ice extent. As a prelude to the inclusion of calculations of sea-ice extent in coupled ocean–atmosphere models, the sensitivity of the atmospheric general circulation to such changes has been demonstrated by an integration in which all the Antarctic sea-ice north of latitude 66°S was removed throughout the austral winter. This is roughly equivalent to replacing the winter distribution of sea-ice with that found in summer. The Antarctic circumpolar trough in the sea-level pressure field was substantially deeper than in a control integration with climatological sea-ice extents, and was displaced to the south for most of the winter period.

In all the climate change experiments performed so far, cloud amounts have been prescribed from climatology. Methods of determining the cloud distribution from model parameters have been tested and assessed for suitability in climate studies. One scheme which has been developed produces satisfactory cloud distributions except in a few areas, such as the polar regions in summer, where the atmospheric model's climatology is known to be deficient, and over mountains where the model is too moist and hence too cloudy, owing to shortcomings in the treatment of subgrid-scale diffusion. A realistic diurnal cycle is obtained provided the cloud and radiative heating are updated sufficiently often.

One difficulty encountered in climate change experiments is that of distinguishing differences which arise from the mechanism under test from differences which arise through the numerical model's inherent variability. Some guidance may be gained from simple statistical tests, which are used to indicate those differences which are unlikely to have occurred by chance. An interesting result obtained this year is that tests made on seasonal mean differences appear to be more discriminating than those made with the individual monthly means over the same period, even though the sample size is three times smaller.

Simulations of climate are usually compared with long-term averages from climatology. Recently, more emphasis has been put on an ability to reproduce the variability of the real atmosphere. A comparison of simulated and observed daily data over eastern England has shown that the simulations produced realistic cold spells in winter and spring, usually in association with easterly winds, but they occurred more often than observed. Also the simulations had fewer dry spells than observed. In one climate change experiment studied, the number of cold easterly outbreaks was considerably reduced, leading to a greater reduction in the frequency of frosts than would be expected from the mean change in temperature alone. This emphasizes the necessity of using three-dimensional time-dependent models to examine possible changes in climate.

Work on the development of an ocean modelling capability has continued in recognition of the need for coupled ocean–atmosphere simulations in climate research. There are three distinct components in the ocean model which is being developed; these are the representations of currents throughout the ocean depth, of the vertical mixing processes which are very important in an upper layer of the ocean adjacent to the surface, and of the sea-ice floating at the surface.

Experiments in which the mixed layer component of the ocean model is coupled to an atmospheric general circulation model, with sea ice extent also calculated interactively but ocean currents neglected, have now been set up on the CYBER 205. Early experiments of this type have shown that the modelled ocean is very sensitive to shortcomings in the atmospheric simulation near the surface. This arises from the coupling procedure, whereby appropriate forcing parameters (heat and moisture fluxes, surface stress and wind-mixing energy) are passed from the atmospheric to the oceanic model which, in turn, provides the atmospheric model with the sea surface temperature field. It is becoming clear that the atmospheric simulation must satisfy stringent requirements of accuracy if the coupled system is to reproduce a realistic seasonal cycle of sea surface temperature. Global data sets of observed values of the forcing parameters are being assembled, both for verification purposes and in order to test the ocean simulations separately from the atmospheric model.

Further studies using the sea-ice model have emphasized the need to include representations of ice dynamics and of processes occurring in 'leads' (areas of open water within a generally ice-covered ocean) where interchange of heat and moisture with the atmosphere is particularly high. Development of these features is under way with the co-operation of the Scott Polar Research Institute at Cambridge.

The dynamical model of currents throughout the ocean depth has also been programmed for the CYBER 205, although changes to permit flexibility in spatial resolution and to improve computational efficiency are still in progress. Experiments aimed at examining the effects of spatial resolution on the development of the simulated ocean circulation have been carried out in co-operation with the Department of Applied Mathematics and Theoretical Physics, University of Cambridge.

Middle atmosphere research

The middle atmosphere, extending from about 10 km to about 100 km in altitude and including the stratosphere and mesosphere, is being studied as part of the total climate system. A special long-term aim of middle atmosphere research is an improved understanding of the factors controlling the ozone layer, so that scientific assessment of possible consequences of man's activities may be soundly based.

Observations for a period of four years are now available from the Stratospheric Sounding Units (SSU) on board the TIROS–N series of satellites. The daily sequence of geopotential fields at stratospheric levels, obtained by objective analysis of layer thicknesses retrieved from SSU and other TIROS–N radiance measurements, provides a basis for climatological investigations and case studies. These observational studies are complemented by numerical integrations of a global numerical model of the stratosphere and mesosphere, both for simulation of atmospheric flow and for the testing of theoretical concepts by controlled numerical experiments. The stratosphere–mesosphere model in its present form has 32 layers between altitudes 16 km and 80 km, but can readily be used with other upper and lower boundary levels.

A range of meteorological fields is being derived from the daily analyses back to November 1978 so that dynamical processes involved in the seasonal evolution of the stratospheric circulation may be investigated. The distinctive characteristics of the flow in the northern and southern hemispheres have been clarified, including differences in the zonally meaned flow in winter, the closely associated differences in the tropospherically forced planetary waves, and the different nature of the seasonal transition from winter westerlies to summer easterlies.

The development of a representation of radiation in the stratosphere–mesosphere model has reached the stage where climatological simulations can be attempted. With the lower boundary height field specified from observations, 30 day integrations with fixed January and July conditions have been completed. During these runs the stratospheric zonally meaned flow remained in broad agreement with the climatological information derived from SSU measurements, and the marked interhemispheric differences in the winter circulations were faithfully reproduced. This result suggests that a key requirement for accurate simulation of the polar night jets in troposphere–stratosphere general circulation models is an adequate simulation of the tropospheric forcing.

The numerical and theoretical studies of the 1978/79 winter described in last year's Report have been extended by a number of experiments seeking to isolate the crucial features in various case studies. More accurate numerical approximations have been implemented in the stratosphere–mesosphere model, and have been tested using the February 1979 simulations. Improvements in the model's formulation will continue to be sought, especially since it will eventually provide the basis for the Office's program of dynamical assimilation of observations from the Upper Atmosphere Research Satellite now under development by the US National Aeronautics and Space Administration.

During the year the Office participated in an international comparison of meteorological analyses at stratospheric levels. Attention was focused on several days in the 1978/79 winter, and analyses based on several distinct data sources (radiosondes and three different satellite radiometers) were compared. The results showed encouraging agreement between the different analyses and observations, even during periods of rapid change, and the agreement extended to the more demanding derived quantities such as heat and momentum fluxes. Several areas were noted where further work is required, including the treatment of regions of missing data and the effects of tidal components.

Special investigations

Many requests for meteorological advice are received which require more than the routine extraction of data or the straightforward application of meteorological theory. Unless they are so specialized as to require the attention of one of the main research Branches, they are usually handled in the Special Investigations Branch, which has built up considerable expertise in assembling fact and theory from diverse sources and applying the results to practical problems. Mostly, the problems have arisen from the needs of aviation either directly in relation to aircraft operations in adverse weather conditions, or indirectly through the development of techniques for forecasting parameters required by aviation.

The numerical forecasting models now in operational use are capable of providing more detailed information, particularly about conditions close to the earth's surface and in the lower troposphere where many of the problems are encountered, than has been available in the past. As a result, the emphasis of work relevant to aviation has been shifting to the development of forecasting techniques based on the output of the operational numerical model and its interpretation in terms of local weather. The investigations are expected to be valuable not only in themselves but as a step in the process of evaluating and improving the new 15-level model.

The increasing use of helicopters in bad weather has led to a need for better information on the probability of encountering severe icing or heavy snow. This is being met by a program of observations from the MRF aircraft and by preparing a climatology of icing conditions. A most important source of data for the latter is a unique set of cloud observations obtained on about 15 000 aircraft reconnaissance flights made during and after World War II. The observations had been put into machinable form and are being processed.

Aviation authorities have long been concerned about the effect of low-level wind variations (now referred to as 'wind shear') on the handling of large jet aircraft. As a result of studies in the Branch, a wind-shear alerting service has been in operation at Heathrow since May 1982, and its extension to other airports is under consideration. A related problem is the fact that the wind supplied by Air Traffic Control (ATC) to aircraft about to land or take off is based on an anemometer which may be unrepresentative of the wind experienced by an aircraft flying up to 3 km away. Automatic digital logging equipment was attached to the two Heathrow anemometers (3.2 km apart) for one year to investigate the frequency distribution of wind differences. In addition, a study of the mode of presentation of wind speed and direction to ATC has led to recommendations to output an average wind for ATC use which will be considered by the Windshear Committee of the Civil Aviation Authority.

There is a steady demand for climatological data. Recent examples have been the prompt preparation of a climatic brief for the recent Task Force operations in the South Atlantic. Advice and information are also being given for the preparation of a MOD Environmental Handbook for Defence Equipment. Additionally demand for climatological data tailored for aviation needs remains high.

A forecast product used by airlines is the significant weather chart, which indicates areas where clear air turbulence, icing and thunderstorms are likely to occur. At present, they are prepared by a forecaster, but it has been recommended by International Civil Aviation Organization (ICAO) that they should be generated as numerical model output. Numerical forecasts of a probability of encounter with at least moderate clear air turbulence per 100 km of flight have been produced operationally for the past year in parallel with the manual product. This forecasting technique is now being adapted for use on the new operational 15-level model. The development of techniques to delineate from numerical forecasts areas of deep convection and of icing has begun.

In forecasting upper winds for aviation a parameter of particular interest is the 'equivalent headwind'—or the average magnitude of headwind experienced by an aircraft along its route. In flight planning, airlines use wind forecasts to choose routes with, other circumstances permitting, the lowest possible value. A scheme for monitoring errors in this quantity in forecasts by the new 15-level model has been developed; it uses winds measured by aircraft equipped with the Aircraft Inertial Data Systems (AIDS) to determine the true equivalent headwinds along their routes.

The development of forecasting techniques at outstations is being helped as a result of the introduction of outstation automation. This allows an increasing use of various kinds of synoptic and satellite information. Additionally, there is some prospect of monitoring the local structure of the atmospheric boundary layer by using cheap mini-sondes. The role of the Special Investigations Branch is to develop methods of using this information to improve forecasts issued by outstations. To this end, a small team helps and encourages outstation staff to carry out their own investigations. Computer services for the provision of data and guidance on methods of analysis and interpretation of results are given. These services are also provided for student projects at the Meteorological Office College. This team is also developing mesoscale analysis techniques to improve the local forecasting of fog, showers, stratocumulus and surface temperatures. For the last a study of the physical causes of the extreme screen minima observed during the winter of 1981/82 has produced interesting results.

Three centrally directed field projects are being carried out at outstations:

(1) At RAE Bedford an acoustic sounder for measuring fog-top height and a low starting-speed anemometer for use in fog forecasting have been installed, and it is planned to supplement these with mini-sondes released during foggy periods in the winter of 1982/83.

(2) At two outstations, forecasts of the probability of precipitation up to three days ahead were made during the period April 1981 to October 1982 for comparison with numerical model forecasts. The object is to improve precipitation forecasts, particularly for agriculture.

(3) A method of forecasting the surface temperature of concrete and tarmac areas is being developed based on observations made with probes just below concrete and tarmac surfaces at Lyneham. Temperatures on such surfaces determine icing conditions on runways and roads.

An analysis of the climatological distribution of Sferic sources (atmospherics or the radio interference generated by lightning flashes, and used to locate thunderstorms) has been completed. The patterns obtained correlate well with those derived from surface reports of thunderstorms but have a more extensive coverage including, for example, remote land areas and sea areas. The information will be used for enquiries on radio propagation, as well as others involving conventional meteorological parameters such as atmospheric stability.

Advice is given to firms in the chemical industry in forecasting the spread of chimney plumes and to help them plan emergency action in the event of a serious leakage of dangerous contaminant. A climatology of the frequency distribution and intensity of atmospheric temperature inversions has been completed, and related to the mode of dispersal of chimney plumes.

A commitment to process field data obtained from the site of a proposed nuclear power station at Torness in Scotland has also been undertaken. Because this is a coastal site with high ground not far inland, there are special problems in assessing the dispersion climatology of material accidentally released from Torness which require special investigation.

Radio meteorological enquiries are also handled, and are principally concerned with the effects of precipitation and evaporation ducting on microwave communication links. One enquiry handled recently was the assessment of a device claimed to indicate real-time ducting properties of the atmosphere in an operational context.

LIBRARY, EDITING, PUBLICATIONS, ARCHIVES AND CARTOGRAPHY

The National Meteorological Library forms part of the Meteorological Office Headquarters at Bracknell. It is used mainly by the staff of the Office but there is also a large demand for its services from universities, schools, commercial and industrial firms and the general public.

The Library has comprehensive holdings in its field, particularly of overseas climatological data, and is often able to supply information not readily available anywhere else in the world; microfiche copies of some 24 000 pages of the bibliographies were sent on repayment to one foreign institute. The Monthly Accessions List, generally available by the 20th of the following month, contains on average some 750 entries and is the most up-to-date listing in the field. The production of this Accessions List and other work connected with Accessions is greatly helped by the computer-based Meteorological Office Library Accessions and Retrieval System (MOLARS) and all accessions since 1972 (110 000 items) are now recorded on the data base; unfortunately, the development of the second stage of MOLARS—search and retrieval—was in abeyance throughout the year.

The union catalogue of rare books (i.e. published before 1850) held by the Royal Meteorological Society and the Library has been prepared using MOLARS and will be made available on microfiche.

Although the number of overseas daily weather reports received on exchange continued to fall, there was some increase in the number of other publications in our field, mainly of a commercial nature. To meet financial constraints the purchase of journals and books for the Library and for supply or circulation to outstations was kept under constant review. Accessions to the Visual Aids unit continued at a high level, particularly of satellite material. Liaison with other Government and local libraries has been maintained leading to savings in time and money.

Loans continued at about the same level as last year but the proportion lent to outside users increased to 17 per cent mainly through the British Library inter-library lending voucher scheme. Visual Aid loans were about the same, again with a large proportion of loans to outside users.

The use of microfiche has increased appreciably owing in part to the wider availability of fiche-viewers in Headquarters after the introduction of Datagraphix equipment by the Data Processing Branch. Some outstations also have viewers, and the greater use of microfiche will lead to savings in copying and postage.

Enquiries continued to cover a wide range. Examples of topics treated were hourly pressure values at Macao, levanter cloud over Gibraltar, smog in Turkey, air pollution in Brazil and—in the historical field—weather in London during the summer of 1688, European weather in July and August 1801, data relevant to the spread of potato blight in 1845, and the use of Spitfires for meteorological reconnaissance flights.

Support was given as necessary to the Defence Services Branch for the operations in the South Atlantic.

The Editing Section prepares for printing most of the official publications of the Office. The increased volume of work noted last year has been maintained, but with a higher proportion of the total being represented by Branch publications, which are typeset 'in-house' and printed using facilities provided by the Ministry of Defence. Major works, such as the *Annual Report*, handbooks and the monthly *Meteorological Magazine*, are passed to Her Majesty's Stationery Office (HMSO), with which the Section has close contacts. A summary of Meteorological Office titles published during 1982 appears in Appendix IV.

The Publications Section handles the distribution of scientific journals, textbooks, works of reference, and a variety of administrative material; they also organize the distribution of technical forms to outstations and co-operating observers, copies of departmental publications, other than those intended purely for use within the Meteorological Office, are sent regularly to Chadwyck-Healey Ltd., of Cambridge, for inclusion in the Catalogue of British Official Publications (not published by HMSO).

Close liaison with the Copyright Section of HMSO on matters concerning the use of Crown Copyright material by outside publishers has continued. The number of copyright enquiries dealt with remains fairly constant at around ten a month.

Meteorological observations in manuscript and other original documents and records are kept, in accordance with the Public Records Act 1958 and the Public Records (Scotland) Act 1937, in special repositories (archives) in Bracknell, Edinburgh and Belfast. The material in these archives is consulted by a large number of people from both inside and outside the Office.

The Cartographic Section prepares artwork for Meteorological Office publications, for internal memoranda, and for papers contributed to scientific journals by members of the staff. It also prepares data-entry forms, exhibition displays, viewfoils, slides and lecture aids, and the large number of diagrams and charts for various areas of the world that are used for manual and automatic plotting of meteorological observations or for transmission by facsimile machines. The Section liaises directly with contract printers assigned by HMSO; almost all maps, charts and data-entry forms are handled in this way. In addition, a large volume of miscellaneous printing is dealt with by use of Ministry of Defence reprographic facilities.

Statistics on the work of the Library, Archives and the Cartographic Section are given in Table XVI (page 128).

Professional Training

Policy on the professional and Managerial training of Meteorological Office staff is determined by the Meteorological Office Training Board, under the chairmanship of the Director-General. Most of the formal professional training is carried out at the Meteorological Office's own residential College or its School of Technical Training. Some staff, however, attend specialist courses outside the Office. The College maintains contacts with neighbouring Colleges of Technology, the University of Reading, the European Centre for Medium Range Weather Forecasts (which is next door), the British Council, the Royal Naval School of Meteorology and Oceanography, the Royal Electrical and Mechanical Engineers' School of Electronic Engineering at Arborfield and other relevant bodies.

The Meteorological Office College is situated at Shinfield Park, south of Reading. It accommodates just over 100 students and carries out training in basic meteorology as well as in forecasting, observing and related topics. The College is well equipped for class-room teaching, for making instrumental observations, for field-work, for the analysis and use of meteorological data and for briefing training, including the use of closed-circuit television and video recording. It has a cinema which seats 94, two lecture theatres and 13 class-rooms, including one designed for tuition on instruments. It has a computer with seven visual display units for students' use: the computer can be linked to the COSMOS main-frame computer at Bracknell. An important part of many courses is the simulation of the work in operational forecasting offices. For this purpose, current meteorological observations from many parts of the world, including those obtained by satellites, are received by teleprinter, by facsimile and through the computer link.

The grounds of the College provide room for field-work, the siting of instruments and for relaxation. Cricket, football. putting and croquet are played in the Park. Other recreational facilities include three tennis courts, a squash court, a bar and rooms for table tennis and television (fitted to receive Teletext broadcasts).

When the College is full, some courses are accommodated at Boundary Hall, Tadley, some 10 miles away, and are transported to and from the College by private coach. Teaching is always at the College but students on such courses may use recreational facilities at both Shinfield Park and Boundary Hall.

Whilst most courses are designed for staff of the Meteorological Office, when places are available they are open to students nominated by other meteorological services. Occasionally courses are devised and run entirely for members of other services. Fees are paid in advance. Enquiries should be addressed to: The Principal, Meteorological Office College, Shinfield Park, Near Reading, RG2 9AU.

The number of officers who completed each of the various courses during the year are listed in Table XVII. Whilst there has been only limited recruiting of Assistant Scientific Officers, in-service up-dating and overseas students kept the College busy during the academic year. Tight manning at stations meant that some courses were undersubscribed. This, coupled with consequences of the Falklands operations, resulted in the cancellation of a small number of courses.

The training of technical staff has continued at the School of Electronic Engineering, Arborfield, at Shinfield Park or at Beaufort Park depending on the stage of training and the facilities required. The widespread introduction into operational use of equipment using advanced technology has intensified the task of re-training field technical staff and has increased the amount of time instructors of the School of Technical Training need to prepare courses on newly introduced equipment. Members of overseas services received 100 man-weeks of work experience or training on the job during the year.

The effort of training meteorological members of overseas services on the job totalled 130 weeks. Numbers of overseas students on formal courses are shown in Table XVII; they are rather fewer than in 1981, probably a reflection of the world economic situation. About half of these meteorologists from overseas are funded by their own governments and about half by international funding through the United Nations Development Project, International Civil Aviation Organization (ICAO), World Meteorological Organization (WMO) and British Technical Assistance. Some are also funded through UK participation in the Voluntary Co-operation Program (VCP) of WMO. The UK contribution to VCP this year is summarized in Table XVII.

In addition staff continue to be encouraged to improve their academic qualifications. In the academic year 1981/82 six members of the staff were on special leave with pay studying full-time for Honours degrees in relevant subjects and 3 were studying part-time for PhD in conjunction with co-operating universities. All of those who took their examinations this year graduated, two as BSc (one with First Class Honours), one as BTech and two as PhD. More statistics of this important part of the training of Office staff are given in Table XVII.

General Activities of the Research Directorate

The Meteorological Office continued to work closely with a number of national and international bodies which are concerned with meteorological research. The Office provided representatives on a number of research-oriented committees of the Royal Society, the Natural Environment Research Council and the Science and Engineering Research Council. In the international field, scientists from the Office serve on several working groups of the World Meteorological Organization and of the International Association of Meteorology and Atmospheric Physics.

Support for research in Universities was provided through the Gassiot Grants Committee which met once, in June, and recommended the award of 5 grants totalling £40 000. Eleven research students provided a valuable link with university research by carrying out a part of their work in the Office under the Co-operative Awards in Science and Engineering (CASE) scheme. Several members of university staffs worked in the Office as consultants for short periods, and there were numerous visits from overseas scientists.

P. Goldsmith
Director of Research

STATISTICS OF THE RESEARCH DIRECTORATE

TABLE XVI—LIBRARY, ARCHIVES AND CARTOGRAPHIC SECTION

Library	
Publications received:	
Books, journals, etc.	7628
Daily weather reports	7825
Films, slides and photographs	2890
Individual books, pamphlets, articles, etc. classified and catalogued	10 553
Publications lent:	
Books, journals, etc.	17 199
Daily weather reports	8062
Films, slides and photographs (250 occasions)	8495
Requests met by photocopies or copy microfiche	1394
Number of exchange agreements	1098
Number of pages translated by MOD translators	274
Archives	
Documents received from Headquarters Branches:	
Charts for permanent retention	26 600
Charts for limited retention	26 400
Ships' logbooks	1270
Rainfall cards for 1979 (number of stations)	5060
Documents received from outstations:	
Daily Registers	1306
Autographic charts (station-months)	6043
Enquiries dealt with:	
Loans to Headquarters Branches	210
Cartographic Section	
Number of diagrams, maps and charts completed during 1982	3301
Number of reprographic jobs during 1982	502

TABLE XVII—TRAINING

The following figures give details of courses completed during 1982 at the Meteorological Office training establishments at Shinfield Park and Beaufort Park.

	Number of courses	Length in weeks	Met. O. staff	Others	Total
Scientific Officers Part II (1981)	1	6	18	6	24
Scientific Officers Part I (1982)	1	14	14	2	16
Applied Meteorology Part II (1981) (Forecasters)	1	8	1	3	4
Applied Meteorology (Prep) (1982)	1	3	8	3	11
Applied Meteorology Part I (1982)	1	10	15	10	25
Applied Meteorology Part II (1982) (Support Scientists)	1	1	9	0	9
Initial Forecasting (Prep)	1	2	5	5	10
Initial Forecasting	1	17	12	9	21
Advanced Forecasting	3	7	25	5	30
Advanced Forecasting	1	6	8	3	11
Extension Course	3	4	25	5	30
Further Extension Course	1	2	7	0	7
Senior Meteorologists	1	3	12	1	13
Meteorological Statistics	1	4	9	1	10

TABLE XVII (*continued*)

	Number of courses	Length in weeks	Met. O. staff	Others	Total
Tropical/Mediterranean Meteorology	1	3	0	8	8
Initial Programmers	2	4	11	0	11
Initial Programmers	1	3	9	0	9
COSMOS Programmers	2	2	12	1	13
Basic Assistants	2	4	17	0	17
Initial Assistants	2	4	16	0	16
Advanced Assistants	8	4	86	2	88
Extension Assistants	1	4	13	0	13
Scientific Officers (Supervisors) ..	1	4	8	0	8
Scientific Officers (Supervisors) ..	1	3	7	0	7
Initial Supervisors	2	3	20	0	20
Auxiliary Observers	5	1	0	58	58
Co-operating Observers	5	1	0	53	53
Air Traffic Control Observers ..	8	1	0	90	90
*ASO to R(M)T Conversion (1981)	1	55	10	0	10
Public Services Meteorology ..	1	1	10	0	10
Management, Scientific and Technical	1	0.6	16	0	16
Introduction to Meteorology for Non-Met. Staff	1	1	9	0	9
Digital Anemograph Logging Equipment (DALE)	3	1.6	25	0	25
Digital Anemograph Logging Equipment (DALE) (Specialists) ..	1	1	4	0	4
Mk IV Wind System	1	0.8	10	3	13
Mk V Wind System..	3	0.4	25	0	25
Synoptic Automatic Weather Station (SAWS)	1	1.7	6	0	6
Synoptic Automatic Weather Station (SAWS)	1	2	8	0	8
Met Office Data Logging Equipment (MODLE)	1	1.8	5	0	5
Crosswind Resolver..	1	0.4	10	1	11
Cloud-base Recorder Mk 3A and Mk 3B	1	2	10	1	11
Facsimile Transmitter K.150 ..	1	0.6	10	1	11
Facsimile Recorder TR4	1	2	10	5	15
Satellite Facsimile Recorders IVa and IVc	1	2	10	0	10
Mk 5 Temperature Bridge	1	0.6	10	0	10
Speech + Duplex	1	0.4	10	0	10
Cossor Windfinding Radar Type MOWFR 4	1	3.8	10	0	10
Digital Temperature Indicator ..	1	0.6	10	0	10
Totals			585	276	861

*Course carried out for the Meteorological Office by the School of Electronic Engineering, REME Arborfield, Berks., from January to May, thereafter by Met O 16 at Shinfield Park.

TABLE XVII (*continued*)

Students from the following territories attended courses which terminated during 1982.

	Number of students
Bahrain	2
Bangladesh	1
Belgium	2
Cyprus	2
Guernsey	1
Hong Kong	19
Territories served by International Aeradio Ltd	4
Iraq	2
Isle of Man	1
Jersey	1
Malaysia	8
Malta	3
Netherlands	1
Nigeria	1
Pakistan	1
Switzerland	3
Uganda	1
Yemen	1
Zambia	1
Zimbabwe	6

Training in the United Kingdom during 1982 under the Voluntary Co-operation Programme of the World Meteorological Organization

Institute	Training	Duration	Country
University of Essex	Diploma in Telecommunications	1 year	Botswana
Heriot-Watt University	MSc Computer Science	1 year	Uganda
Meteorological Office	AFC* + OJT	4 months	Iraq
Meteorological Office	AFC + OJT + EC	4 months	Pakistan
Meteorological Office	AMC + OJT	8 months	Zimbabwe
Reading College of Technology	Basic Electronics	2 years	Jamaica
Reading College of Technology	Basic Electronics	2 years	Kenya (2)
Reading College of Technology	Basic Electronics	2 years	Seychelles
Reading College of Technology	Basic Electronics	2 years	Zimbabwe
University of Reading	BSc Meteorology	4 years	Ghana
University of Reading	BSc Meteorology	4 years	Nepal
University of Reading	BSc Meteorology	4 years	Netherlands Antilles
University of Reading	BSc Meteorology	4 years	Tanzania
University of Reading	MSc Agro-meteorology	2 years	Tanzania (2)
University of Reading	MSc Meteorology	2 years	Ghana

*AFC = Advanced Forecasting Course
OJT = Training on the job
EC = Extension Course for Higher Scientific Officers
AMC = Applied Meteorology Course

TABLE XVII (*continued*)

External training—academic year 1981/82.

	Number of students
Full time	
First Degree	6
Part time	
Higher Degree	3
First Degree	2
TEC/BEC, HNC (including block release at Reading College of Technology	65
ONC/A-level	56
O-level	1
Miscellaneous	6
Day release (under 18 years)	
Secretarial	1
Further education	
Open University	26
Other Science and Mathematics	11

ADMINISTRATION

Personnel Management

The Personnel Management Branch (Met O 10) provides a wide range of services to the Senior Directorate, to line managers and to individual members of staff of the Meteorological Office. In 1982 the Branch assumed much of the responsibility for administering complements in the Office, and this involved increased liaison with the trade unions and a strict scrutiny of complement and strength numbers to ensure that total manpower remained below the imposed ceiling. Activities during the year were inevitably influenced by the requirement to continue the reduction in staff numbers. During the first quarter of 1982, some 15 staff left the Office on premature retirement; subsequently the reduction in numbers was easily achieved through normal retirement and secondment to other organizations.

Despite the reduction in total strength, there was still the capacity for a limited recruitment of well-qualified graduates, of whom 14 were appointed, and of basic-grade staff including a few in clerical and industrial grades. The competition for Assistant Scientific Officer recruitment began in May, and the response to advertising of vacancies nationally was almost overwhelming; over 2000 applications were received and clerical resources were severely stretched by processing this large number. By the end of the year, about 50 new ASOs had been recruited. To replace MOD Police at the Bracknell Headquarters, 10 civilian security officers were recruited. As in previous years, several university and polytechnic students were employed for limited periods as vacation students or for the industrial training element of sandwich degree courses.

Manning of some of the Office's operational posts was seriously affected by the Falklands operation. Staff in the Mobile Meteorological Unit were deployed to Ascension Island and subsequently to Port Stanley, and the vacancies created by their absences had to be filled by redeploying other staff at home. The Central Forecasting Office was also strengthened during the conflict, leaving unfilled posts for a time elsewhere. During 1982, the average number of movements was 25 a week.

During the year, Career Development Officers became increasingly involved in negotiations with line managers over staff movements, especially whenever a vacancy could not be filled immediately. Career Interviews were carried out with staff in need of advice on their performance, and the training courses in the skills of Staff Reporting and Job Appraisal Review were maintained at the levels set in recent years. Liaison was maintained with MOD Civilian Management Training Division to ensure uniformity of standards with the Scientific Civil Service as a whole. The Training Liaison Officer continued to advise staff and arrange their attendance on both management and professional training courses. In close co-operation with the College he co-ordinated applications for external training and further education study.

International co-operation
The following staff were released by the Office during 1982 for service with international and other organizations:

Mr C. A. Brimacombe	HSO	European Space Agency
Mr D. R. Kindred	HSO	European Space Agency
Mr M. J. Crisford	SO	International Aeradio Ltd
Mr. A. Darlington	SO	International Aeradio Ltd
Mr R. Dunn	SO	International Aeradio Ltd
Mr P. R. Edge	ASO	International Aeradio Ltd
Mr P. Framingham	HSO	International Aeradio Ltd
Mr D. Ireland	HSO	International Aeradio Ltd
Mr C. Lakeland	ASO	International Aeradio Ltd
Mr H. Moss	HSO	International Aeradio Ltd
Mr P. L. Stewart	HSO	International Aeradio Ltd
Mr R. J. Stretch	SO	International Aeradio Ltd
Mr G. W. Sutton	SO	International Aeradio Ltd
Mr L. P. Stevens	HSO (T/SSO)	Caribbean Governments

Staff returning from international and other secondment appointments were:

Mr L. P. Stevens	HSO (T/SSO)	Antiguan Government
Dr T. N. Palmer	SSO	University of Washington, USA
Mr J. Morgan	PSO	European Space Agency

Staff numbers
At the end of the year 1982 the total number of posts, of all grades, was 2815, a decrease of 70 over the year. The actual strength at the end of the year was:

Deputy Secretary	1
Under Secretary	1
Science Group	
Chief Scientific Officer	2
Deputy Chief Scientific Officer	6
Senior Principal Scientific Officer	25
Principal Scientific Officer	109
Senior Scientific Officer	277
Higher Scientific Officer	479
Scientific Officer	442
Assistant Scientific Officer	721
Administrative Group	
Assistant Secretary	1
Principal	1
Senior Executive Officer	2
Higher Executive Officer	8
Executive Officer	17
Clerical Officer	47
Clerical Assistant	57

Ocean Weather Ship	
Officers and non-industrial grades	1
Professional and Engineering Group (including Marine Superintendent staff)	
Superintending Engineer	1
Principal Professional and Technology Officer	3
Professional and Technology Officer Grade I	5
Professional and Technology Officer Grade II	19
Professional and Technology Officer Grade III	4
Professional and Technology Officer Grade IV	4
Telecommunications Staff	
Telecommunications Technical Officer Grade A	1
Telecommunications Technical Officer Grade I	10
Telecommunications Technical Officer Grade II	27
Telecommunications Technical Officer Grade III	64
Radio (Meteorological) Technician	43
Signals grades	79
Teleprinter grades	60
Typing and miscellaneous non-industrial grades	111
Security officers	10
Industrial employees	67
Locally entered staff and employees overseas	51

EQUIPMENT

Financial constraints, and in particular the tight control on equipment Votes, have again contributed to delays in the introduction of new equipment. In addition to the support of existing systems, the Meteorological Office supply organization contributed to the support of the Falklands Task Force in procuring meteorological instruments and other equipment at short notice.

FINANCE

Except for the services provided by the Property Services Agency (PSA) on an allied service basis, the cost of the Meteorological Office is borne on Defence Votes to which all receipts from repayment services are also credited. This year has seen the proposals to introduce the Property Repayment System (PRS) by the PSA and the Headquarters buildings of the Meteorological Office together with certain outstations in the Civil estate will in future be charged a rent related to commercial practice. Other outstations are included in the Defence estate and as such will not be included in the PRS.

The finance section of the Secretary's department has continued the financial control of cash expenditure and receipts accounting. The cost and management function has been heavily involved in the enquiries of the Resource Control Review and the need for strengthening this aspect of accounting has been recognized by the establishment of an additional Cost and Management Accountant. Work on the introduction of the Management Accounting and Information System (MAIS) has progressed and an Integrated Database Management System installed. Many of the preparatory data have been entered into the system, with payroll data from the Accounts Directorate translated to the IBM format suitable for use in the system. A new Staff Time Analysis procedure is progressing well towards its introduction in April 1983 with input forms standardized to meet HQ and outstation requirements.

The following tables are drawn directly from the Memorandum Operating and Trading Account (MTA). They differ from the format used last year when certain cost items in the MTA were excluded from the tables, resulting in some confusion and misunderstanding. It should be noted, however, that the MTA figures in the tables differ from the Voted figures of expenditure and receipts which are contained in the Annual Statement of Defence Estimates. This is because the figures in the tables include costs which are not included in Voted figures, such as depreciation, notional insurance, MOD HQ costs attributable to Meteorological Office, and interest on capital. By the same token, the capital costs of major items of expenditure, such as computers, are excluded from the figures in the tables although they appear in Voted expenditure in the year of acquisition.

The tables include figures for the previous year 1980/81 for comparison. These are shown on the same basis as the current year figures except that the abolition of the preferential Exchequer rates charged to other Government Departments for repayment work from 1 April 1981 means that the comparison is not strictly valid. Charges for repayment work were increased by 9 per cent with effect from 1 January 1982. This increase included staff pay awards and increased provision for pensions and gratuities, the latter element being included by direction of the Treasury.

STATEMENT OF THE COST OF METEOROLOGICAL SERVICES FOR THE YEAR ENDED 31 MARCH 1982

	1981/82		1980/81	
	£000	£000	£000	£000
Total meteorological services (cost accounted)		52 309		50 477
Receipts				
Training and secondments	187		259	
Exchequer Departments	784		281	
Non-Exchequer bodies	14 097		13 876	
Industry and commerce	1539		1307	
General public	73		39	
		16 680		15 762
Net expenditure				
Defence	18 833		18 305	
Civil	15 189		14 273	
International	1221		1649	
Exchequer Departments	386		488	
		35 629		34 715

STATEMENT OF OPERATING EXPENSES FOR THE METEOROLOGICAL

(1) Expenditure	(2) Defence Services £000	(3) Exchequer Departments non-repayment £000
Customer activity costs		
Direct labour	2609	45
Other direct costs	144	3
Indirect costs		
Labour	3567	71
Others	1128	19
North Atlantic Ocean Stations (NAOS) receipts		
Depreciation	152	1
General Meteorological Office costs		
Research	3124	55
Observations; Telecommunications; Computing	4411	115
General services		
Central Forecasting Office; Technical support; Maintenance; Training; Administration and Personnel; Others	3227	67
Total Meteorological Office management costs		
Full cost items		
Share of MOD HQ costs; Insurance; Interest on capital: Fixed, Working	471	10
Total Meteorological Office full costs	18 833	386

OFFICE FOR THE YEAR ENDED 31 MARCH 1982

(4) Public Services £000	(5) Inter-national £000	(6) CAA £000	(7) 1981/82 Total £000	(8) 1980/81 Total £000
2590	1427	2005	8676	8003
91	44		282	330
2213	49	2216	8116	7836
923	971	444	3485	3157
	(2578)		(2578)	(2316)
58	438	59	708	866
2795	210	1644	7828	8092
			8555	8089
6300		3629	4542	4718
			1358	1273
			1305	1236
			2414	2379
3629	594	2509	1545	1312
			979	914
			2407	2315
			1376	815
			50 998	49 019
			541	666
			55	63
450	66	314		
			525	557
			190	172
19 049	1221	12 820	52 309	50 477

METEOROLOGICAL OFFICE RECEIPTS 1981/82 (CASH RECOVERABLE)

	1981/82 £000	1980/81 £000
Services to:		
Ministry of Agriculture, Fisheries and Food	512	172
Other Exchequer Departments		
(Department of the Environment etc.)	249	47
Civil Aviation Authority	12 820	12 886
National Environment Research Council	—	27
Other Non-Exchequer Departments	31	107
EEC	97	—
Public authorities etc.	372	78
Meteorological Office College (training of meteorologists)	112	190
Secondments to outside bodies	75	69
Comprehensive forecasting for the offshore oil industry	998	772
Forecasting services tailored to meet users' special needs:		
Ship Routeing Service	114	87
Gas Boards	167	143
Central Electricity Generating Board	158	90
British Rail	22	12
Independent Broadcasting Authority	76	32
British Broadcasting Corporation	79	44
Press	51	11
Other customers' special services	469	770
Automatic Telephone Weather Service (British Telecom)	278	225
	16 680	15 762

F.R. Howell
Secretary
Meteorological Office

STAFF HONOURS AND DISTINCTIONS

Sir John Mason was elected to the Presidency of the British Association for the Advancement of Science for 1982–83.

Dr R. Hide was awarded the Holweck Medal and Prize of the French and British Physical Societies for his work in geophysics.

Mrs J. M. Cowlard was appointed as a Member of the Order of the British Empire in the Queen's New Year's Honours List.

Mrs G. W. S. Simpson (Auxiliary Observer, Eddleston, Peeblesshire) and Mr F. A. Gordon were both awarded the British Empire Medal in the Queen's Birthday Honours List.

Mr T. A. Morris, Mr D. E. Newman, Mr B. F. Deeks, Mr L. J. Whitby and Mr C. W. G. Gazzard were each awarded the Imperial Service Medal.

In the Queen's South Atlantic Honours List, Mr W. R. McQueen and Mr J. Turner were both appointed as Members of the Order of the British Empire for services in support of operations in the South Atlantic from April to June. For such services, Mr R. S. Bell, Mr P. W. Davies, Mr S. W. Galaud, Mr B. Phillips and Mr E. E. Williams each received Permanent Secretary's Letters of Commendation.

APPENDIX I

BOOKS OR PAPERS BY MEMBERS OF THE STAFF

ALLEN, D. M.; Sunshine cards—then and now. *Meteorol Mag*, **111**, 1982, 273–274.

ATKINS, N. J.; 100 mb temperature forecasts for Concorde. *Meteorol Mag*, **111**, 1982, 225–232.

AUSTIN, J.; Planetary wave modelling of the middle atmosphere: the importance of travelling wave components. *Q J R Meteorol Soc*, **108**, 1982, 763–778.

BENDALL, A. A.; Low-level flow through the Strait of Gibraltar. *Meteorol Mag*, **111**, 1982, 149–153.

BENNETTS, D. A. and BADER, M. J.; Precipitation in convective storms: an observational and numerical study. AGEE, E. M. and ASNI, T. (editors), Cloud dynamics. Dordrecht, D. Reidel Publishing Company, 1982, 363–377.

BENNETTS, D. A. and SHARP, J. C.; The relevance of conditional symmetric instability to the prediction of mesoscale frontal rainbands. *Q J R Meteorol Soc*, **108**, 1982, 595–602.

BENNETTS, D. A., BADER, M. J. and MARLES, R. H.; Convective cloud merging and its effect on rainfall. *Nature*, **300**, 1982, 42–45.

BOOTH, B. J.; An analysis of sudden, large falls in temperature at Lyneham during periods of weak advection. *Meteorol Mag*, **111**, 1982, 281–290.

BRADBURY, T. A. M.; Observations of waves in a wide range of conditions. *Aero-Revue, Zurich*, No. 8, 1982, 50–54.

BROOMFIELD, C. S.; Auxiliary reporting station Gorleston. *Meteorol Mag*, **111**, 1982, 97–99.

Synoptic reports from the Isles of Scilly. Ibid., 185–189.

B[ROWN], J. D.; Long association with shipowners—Canadian Pacific Steamships Limited. *Mar Obs*, **52**, 1982, 94–95.

BROWNING, K. A.; Nowcasting. London, Academic Press, 1982.

BROWNING, K. A. and COLLIER, C. G.; An integrated radar–satellite nowcasting system in the UK. BROWNING, K. A. (editor), Nowcasting. London, Academic Press, 1982, 47–61.

BROWNING, K. A. and MONK, G. A.; A simple model for the synoptic analysis of cold fronts. *Q J R Meteorol Soc*, **108**, 1982, 435–452.

BROWNING, K. A., COLLIER, C. G., LARKE, P. R., MENMUIR, P., MONK, G. A. and OWENS, R. G.; On the forecasting of frontal rain using a weather radar network. *Mon Weather Rev*, **110**, 1982, 534–552.

BROWNSCOMBE, J. L. and NASH, J.; Long term monitoring of stratospheric temperature. University of Reading, Department of Geography, Remote Sensing Society. Remote sensing of the Atmosphere, 1982, 2–11.

BURT, S. D.; Heavy rainfall and snowstorms, 23–26 April 1981. *Weather*, **37**, 1982, 108–115.

The curious case of the horizontal icicles. *Meteorol Mag*, **111**, 1982, 183–184.

BUTCHART, N., CLOUGH, S.A., PALMER, T. N. and TREVELYAN, P. J.; Simulations of an observed stratospheric warming with quasigeostrophic refractive index as a model diagnostic. *Q J R Meteorol Soc*, **108**, 1982, 475–502.

CARPENTER, K. M.; Model forecasts for locally forced mesoscale systems. BROWNING, K. A. (editor), Nowcasting. London, Academic Press, 1982, 223–234.

CARPENTER, K. M. and LOWTHER, L. R.; An experiment on the initial conditions for a mesoscale forecast. *Q J R Meteorol Soc*, **108**, 1982, 643–660.

CARSON, D. J.; Comments on the sensitivity of numerical simulations to different parametrizations of the boundary-layer properties and processes. ECMWF Workshop on Planetary Boundary Layer Parametrization, 25–27 November 1981, Reading, 1982, 119–153.

CATTLE, H.; Techniques of prediction. Boston, Mass., American Meteorological Society. International Conference; Climate and Offshore Energy Resources, London, 21–23 October 1980, 1981, 135–136.

CAUGHEY, S. J.; Observed characteristics of the atmospheric boundary layer. NIEUWSTADT, F. T. M. and VAN DOP, H., Atmospheric turbulence air pollution model. Dordrecht, 1982, 107–158.

CAUGHEY, S. J. *in* MOULSLEY, T. J., ASIMAKOPOULOS, D. N. *et al.*; Measurement of humidity using multifrequency atmospheric acoustic sounding. *Atmos Environ*, **16**, No. 6, 1982, 1501–1506.

CAUGHEY, S. J. and CONWAY, B. A. *in* BAKER, M. B., BLYTH, A. M. *et al.*; Field studies of the effect of entrainment upon the structure of clouds at Great Dun Fell. *Q J R Meteorol Soc*, **108**, 1982, 899–916.

CAUGHEY, S. J. and CREASE, B. A. *in* MOULSLEY, T. J., ASIMAKOPOULOS, D. N. *et al.*; Temperature structure parameter measurements using differential temperature sensors. *Boundary-Layer Meteorol*, **23**, 1982, 307–315.

CAUGHEY, S. J., CREASE, B. A. and ROACH, W. T.; A field study of nocturnal stratocumulus: II. Turbulence structure and entrainment. *Q J R Meteorol Soc*, **108**, 1982, 125–144.

CLIFT, G. A.; Report on meteorological radars. WMO instruments and observing methods, Report No. 8, 1981.

CONWAY, B. J., CAUGHEY, S. J., BENTLEY, A. N. and TURTON, J. D.; Ground-based and airborne holography of ice and water clouds. *Atmos Environ*, **16**, No. 5, 1982, 1193–1207.

CULLEN, M. J. P.; The use of quadratic finite element methods and irregular grids in the solution of hyperbolic problems. *J Comput Phys*, **45**, No. 2, 1982, 221–245.

DAVEY, B. A.; Unusual road surface condensation. *Meteorol Mag*, **111**, 1982, 19–22.

DAWE, A. J.; A study of a katabatic wind at Brüggen on 27 February 1975. *Meteorol Mag*, **111**, 1982, 1–13.

DOWNES, C. R.; Changes to the manning of the North Atlantic ocean stations. *Mar Obs*, **52**, 1982, 34–36.

DUTTON, M. J. O.; Prediction of clear air turbulence (CAT): towards probability forecasts based on numerical model output. WMO, Technical Conference on Aviation Meteorology, Geneva, 5–9 November, 1979, Paper 27.

EAGLES, G. R. and SILLS, A. G.; Noise propagation from commercial explosives. Porton Down, Chemical Defence Establishment. Field Trial Report No. 87, May 1982.

ECCLESTON, A. J., CARPENTER, K. M. and COLLIER, C. G.; The use of Meteosat imagery and a network of radars for observing and forecasting rainfall. University of Reading, Department of Geography, Remote Sensing Society. Remote Sensing of the Atmosphere, 1982, 274–281.

EYRE, J. R. and JERRETT, D.; Local-area atmospheric sounding from satellites. *Weather*, **37**, 1982, 314–322.

FIELD, M.; Weather conditions between September 1980 and August 1981. London, Home Grown Cereals Authority. The quality of wheat and barley from the 1981 harvest, 1982.

FISH, M. *in* PARR, M., FISH, M. and TURNER, P.; Bad weather. London, A Zwemmer Ltd, 1982.

FRANCIS, P. E.; The forecasting of state of sea. *Meteorol Mag*, **111**, 1982, 209–217.

FRANCIS, P. E. and PIDGEON, J. D.; A model for estimating soil moisture deficits under cereal crops in Britain. 1. Development, 2. Performance. *J Agric Sci, Cambridge*, **98**, 1982, 651–661.

FRANCIS, P. E., DAY, A. P. and DAVIS, G. P.; Automated temperature forecasting, an application of Model Output Statistics to the Meteorological Office numerical weather prediction model. *Meteorol Mag*, **111**, 1982, 73–87.

GILCHRIST, A.; JSC study conference on observing systems experiments, Exeter, 19–22 April 1982. ICSU/WMO, GARP, WCRP, Numerical Experiments Programme, Report No. 4, 1982.

Prediction using general circulation model. Boston, Mass., American Meteorological Society. International Conference: Climate and Offshore Energy Resources, London, 21–23 October 1980, 1981, 163–164.

GILCHRIST, A. and WHITE, P. W.; The development of the Meteorological Office new operational forecasting system. *Meteorol Mag*, **111**, 1982, 161–179.

GILCHRIST, A., ROWNTREE, P. R. and SHAW, D. B.; Large-scale numerical modelling. ICSU/WMO, GARP Publication Series No. 25, 1982, 183–218.

GLOSTER, J.; Risk of airborne spread of foot-and-mouth disease from the Continent to England. *Vet Rec*, **111**, 1982, 290–295.

GLOSTER, J. *in* DONALDSON, A. I., FERRIS, N. P. and GLOSTER, J.; Air sampling of pigs infected with foot-and-mouth disease virus: comparison of Litton and cyclone samplers. *Res Vet Sci*, **33**, 1982, 384–385.

GLOSTER, J. and HARVEY, L. D. T. *in* DONALDSON, A. I., GLOSTER, J., HARVEY, L. D. T. *et al.*; The use of prediction models to forecast and analyse airborne spread during the foot-and-mouth disease outbreaks in Brittany, Jersey and the Isle of Wight in 1981, *Vet Rec*, **110**, 1982, 53–57.

GLOSTER, J., SELLERS, R. F. and DONALDSON, A. I.; Long distance transport of foot-and-mouth disease virus over the sea. *Vet Rec*, **110**, 1982, 47–52.

GRAHAM, A. E.; Winds estimated by the Voluntary Observing Fleet compared with instrumental measurements at fixed positions. *Meteorol Mag*, **111**, 1982, 312–327.

GRANT, K.; The July lower troposphere over the Middle East. *Meteorol Mag*, **111**, 1982, 179–182.

HARDY, R. [N.] *et al.*; The weather book. London, Michael Joseph, 1982.

HIDE, R.; The giant planets. *Phys Bull*, **33**, 1982, 357–361.

High vorticity regions in rotating thermally driven flows. BENGTSSON, L. and LIGHTHILL, J. (editors), Intense atmospheric vortices. Berlin, Heidelberg, Springer-Verlag, 1982, 313–326.

On the role of rotation in the generation of magnetic fields by fluid motions. *Philos Trans R Soc*, A, **306**, 1982, 223–234.

Rotating fluids in geophysics and planetary physics. *Q J R Astron Soc*, **23**, 1982, 220–235.

HIDE, R. *in* MALIN, S. R. C. and HIDE, R.; Bumps on the core–mantle boundary: geomagnetic and gravitational evidence revisited. *Philos Trans R Soc*, A, **306**, 1982, 281–289.

HIDE, R. and PALMER, T. N.; Generalization of Cowling's theorem. *Geophys Astrophys Fluid Dyn*, **19**, 1982, 301–309.

HIGNETT, P.; A note on the heat transfer by the axisymmetric thermal convection in a rotating fluid annulus. *Geophys Astrophys Fluid Dyn*, **19**, 1982, 293–299.
HILL, F. F.; The location of the thunderstorms on 4 June 1982. *Weather*, **37**, 1982, 328–331.
HOUGH, M. N.; Meteorology and the farmer. MAFF, *Northumberland Divisional Bulletin*, May 1982.
HOUGH, M. N. and BIRD, L. G.; Weather specialists help the farmer. *West Cumberland Farmers' Journal*, April 1982.
HOUGHTON, D. M.; Weather forecasts with 7-language forecast vocabulary. Woking, Royal Yachting Association, RYA Publication G5/82, 1982.
HUNT, R. D.; BBC television weather forecasts—audience research results. *Meteorol Mag*, **111**, 1982, 45–47.

JERRETT, D., EYRE, J. R. and MCCALLUM, E.; High resolution soundings of temperature in the European/North Atlantic area. Bracknell, 1982. Preprint of a paper for presentation at the Proceedings of the Remote Sensing Society, Liverpool, 15–17 December 1982.
JOHNSON, A. I.; Satellites in meteorology, oceanography and hydrology. Geneva, World Meteorological Organization, WMO No. 585, 1982.
JONAS, P. R. and MASON, B. J.; Entrainment and the droplet spectrum in cumulus clouds. *Q J R Meteorol Soc*, **108**, 1982, 857–869.

KEMP, A. K. and MORRIS, S. J.; Line squall and minor tornadoes at Holyhead, 23 November, 1981. *Meteorol Mag*, **111**, 1982, 253–261.
KITCHEN, M. and STIRLAND, E.; A description of the UK Meteorological Office CCN counter. Washington, National Aeronautics and Space Administration, NASA CP–2212, 1981, 33–34 (also in *J Rech Atmos*, **15**, 1981, No. 3–4, 245–247).
KITCHEN, M., LEIGHTON, J. R. and CAUGHEY, S. J.; The response of surface aerosol concentrations to changes in some boundary layer parameters. *Idojaras, Budapest*, **86**, 1982, 254–260.

LAIRD, B.; Lifeboat services. Weather systems for September 19 and 20, 1981 during gales around Britain. *The Lifeboat*, **48**, 1982, 44.
LEWIS, R. P. W.; The Daily Weather Report and associated publications: 1860–1980. *Meteorol Mag*, **111**, 1982, 103–121.
LORENC, A.; Analysis methods for meteorological observations. *Riv Meteorol Aeronaut, Rome*, **42**, 1982, No. 2/3, 155–176.
LYNE, W. H., SWINBANK, R. and BIRCH, N. T.; A data assimilation experiment and the global circulation during the FGGE special observing periods. *Q J R Meteorol Soc*, **108**, 1982, 575–594.

MACKIE, G. V.; The Meteorological Office Ship Routeing Service. *Meteorol Mag*, **111** 1982, 218–224.
Slow realisation of ship routeing benefits. *Lloyd's List*, 27 October 1982, 12.
MASON, SIR [B.] JOHN; The physics of radiation fog. *J Meteorol Soc Jpn*, II, **60**, 1982, 486–499.
Personal reflections on 35 years of cloud seeding. *Contemp Phys*, **23**, 1982, 311–327.
MASON, P. J. and SYKES, R. I.; A two-dimensional numerical study of horizontal roll vortices in an inversion capped planetary boundary layer. *Q J R Meteorol Soc*, **108**, 1982, 801–823.

MOBBS, S. D.; Extremal principles for global climate models. *Q J R Meteorol Soc*, **108**, 1982, 535–550.
Variational principles for perfect and dissipative fluid flows. *Proc R Soc*, A, **381**, 1982, 457–468.
MOORES, W. H.; Direct measurements of radiative and turbulent flux convergences in the lowest 1000 m of the convective boundary layer. *Boundary-Layer Meteorol*, **22**, 1982, 283–294.
MORRIS, R. M.; The accuracy of London Weather Centre forecasts of temperature for the gas industry. *Meteorol Mag*. **111**, 1982, 29–35.
Weather satellite information for offshore industry. *J Navig*. **35**, 1982, 386–396.

NEWMAN, M. R. and GADD, A. J.; Variability in the character of the onset of the SW monsoon in global objective analyses and GCM simulations. ICSU/WMO, GARP International Conference on the Scientific Results of the Monsoon Experiment, Bali, October 1981, Géneva, 1982, 6-42–6-45.
NICHOLLS, J. M. *in* LILLY, D. K., NICHOLLS, J. M. *et al.*; Aircraft measurements of wave momentum flux over the Colorado Rocky Mountains. *Q J R Meteorol Soc*. **108**, 1982, 625–642.
NICHOLLS, S. and SMITH, F. B.; On the definition of the flux of sensible heat. *Boundary-Layer Meteorol*, **24**, 1982, 121–127.

OGDEN, R. J.; Short range forecasting. WMO, Technical Conference on Aviation Meteorology, Geneva, 5–9 November 1979, Paper 26.
O'NEILL, A. and YOUNGBLUT, C. E.; Stratospheric warmings diagnosed using the transformed Eulerian-mean equations and the effect of the mean state on wave propagation. *J Atmos Sci*, **39**, 1982, 1370–1386.
O'NEILL, A., NEWSON, R. L. and MURGATROYD, R. J.; An analysis of the large-scale features of the upper troposphere and the stratosphere in a global, three-dimensional, general circulation model. *Q J R Meteorol Soc*, **108**, 1982, 25–53.

PARKER, D. E.; Large-scale interannual variability of climate. *Meteorol Mag*, **111**, 1982, 193–208.
PICKUP, M. N.; A consideration of the effect of 500 mb cyclonicity on the success of some thunderstorm forecasting techniques. *Meteorol Mag*, **111**, 1982, 87–97.
POTHECARY, I. J. W.; Meteorological services for defence. *Meteorol Mag*, **111**, 1982, 137–148.
PRIOR, M. J.; Weather and the construction industry. *The Quantity Surveyor*, January 1982.
Weather forecasting services for the roofing industry. National Federation of Roofing Contractors Year Book, 1982.

RAWLINS, F.; A numerical study of thunderstorm electrification using a three dimensional model incorporating the ice phase. *Q J R Meteorol Soc*, **108**, 1982, 779–800.
READ, P. L.; The analysis of umkehr observations of stratospheric ozone by a 'maximum entropy' method. *Q J R Meteorol Soc*, **108**, 1982, 719–726.
ROACH, W. T.; Airships: the meteorologist's role. Airship Association, London, *Airship*, No. 54, 1981, 11–17.
ROACH, W. T., BROWN, R., CAUGHEY, S. J., CREASE, B. A. and SLINGO, A.; A field study of nocturnal statocumulus: I. Mean structure and budgets. *Q J R Meteorol Soc*, **108**, 1982, 103–123.
ROE, C. P.; A review of the environmental factors influencing calf respiratory disease. *Agric Meteorol, Amsterdam*, **26**, 1982, 127–144.

Roe, C. P. and McKillop, I. G.; Weather and the spoon-gassing of rabbits. *Meteorol Mag*, **111**, 1982, 36–44.
Roy, M. J.; Grass production in relation to climate. Ashford, Wye College, Centre for European Agricultural Studies, Seminar Paper No. 12, 1981, 53–58.

Sanderson, R.; Meteorology at sea. London, Stanford Maritime, 1982.
Shearman, R. J.; An overview of meteorological services. London, Scientific and Technical Studies. North Sea weather and environment, 1982.
Shone, K. B.; A note on the cold spell of December 1981 in central England. *Weather*, **37**, 1982, 143–148.
The cold spell of late June 1981 in central England. Ibid., 180–182.
Sills, A. G.; Prediction of sound intensity from an explosive source. *Appl Acoust*, **15**, 1982, 231–240.
Slingo, A. and Nicholls, S. *in* Slingo, A., Nicholls, S. and Schmetz, J.; Aircraft observations of marine stratocumulus during JASIN. *Q J R Meteorol Soc*, **108**, 1982, 833–856.
Slingo, A. and Schrecker, H. M.; On the shortwave radiative properties of stratiform water clouds. *Q J R Meteorol Soc*, **108**, 1982, 407–426.
Slingo, A., Brown, R. and Wrench, C. L.; A field study of nocturnal stratocumulus: III. High resolution radiative and microphysical observations. *Q J R Meteorol Soc*, **108**, 1982, 145–165.
Slingo, J. M.; A study of the earth's radiation budget using a general circulation model. *Q J R Meteorol Soc*, **108**, 1982, 379–405.
Smith, C. V.; The role of climatological information in the protection of plants and animals. Geneva, WMO, WMO No. 596, 1982, 251–272.
Climatological aspects of in-harvest and post-harvest losses. Ibid., 302–309.
Smith, F. B. *in* Rodhe, H., Eliassen, A., Isaksen, I. Smith, F. B. *et al.* Tropospheric chemistry and air pollution. Geneva, WMO, *Tech Note* No. 176, 1982.
Smith, S. G.; An index of windiness for the United Kingdom. *Meteorol Mag*, **111**, 1982, 232–247.
Spackman, E. A. and Singleton, F.; Recent developments in the quality control of climatological data. *Meteorol Mag*, **111**, 1982, 301–311.
Storey, A. M.; A study of the relationship between isobaric patterns over the UK and central England temperature and England–Wales rainfall. *Weather*, **37**, 2–11 and 46.

Tabony, R. C.; The estimation of missing values in highly correlated data. Caussinus, H., Ethinger, P. and Tomassone, R. (editors), COMPSTAT 82, Wien, 1982, Part 1, 425–430.
Thompson, N.; Agricultural meteorology: some problems outlined. *Span, Derby*, **25**, 1982, 109–111.
A comparison of formulae for the calculation of water loss from vegetated surfaces. *Agric Meteorol, Amsterdam*, **26**, 1982, 265–272.
Meteorology as an aid to crop protection. Proceedings of the British Crop Protection Council Symposium: Decision Making in the Practice of Crop Protection, Brighton, 6–7 April 1982, 1982, 55–63.
MORECS. Wallingford, Institute of Hydrology, Report No. 78, 1981, 1–10.
Thompson, N. and Ley, A. J.; The quantification of spray drop drift. London, British Crop Protection Council, Proceedings of 1982 Conference—Weeds, Brighton, 22–25 November 1982, 1982, 1039–1044.
Thompson, N., Barrie, I. A. and Ayles, M.; The Meteorological Office Rainfall and Evaporation Calculation System: MORECS (July 1981). *Hydrol Mem, Meteorol Off*, No. 45, 1981.

TUCK, A. F.; Climate, energy and man. Boston, Mass., American Meteorological Society. International Conference: Climate and Offshore Energy Resources, London, 21–23 October 1980, 1981, 5–10.

VAUGHAN, G.; Diurnal variation of mesospheric ozone. *Nature*, **296**, 1982, 133–135.

WALES-SMITH, B. G.; A simple low-cost evaporimeter. *Weather*, **37**, 1982, 353–357.

WASS, S. N.; Computers under glass. *Heat Vent Eng*, **56**, 1982, 6–9.

WATERFALL, P. F.; Where will the heavy rain occur? A study of the heavy rain in Northamptonshire on 26 July 1980. *Meteorol Mag*, **111**, 1982, 58–68.

WHITE, A. A.; Zonal translation properties of two quasi-geostrophic systems of equations. *J Atmos Sci*, **39**, 1982, 2107–2118.

WHITE, P. [W]; Fine mesh models in the UK Meteorological Office. Lecture I: The current operational limited area fine mesh model (the 10-level); Lecture II: The new operational limited area fine mesh model; Lecture III: The mesoscale model. *Riv Meteorol Aeronaut, Rome*, **42**, 1982, 201–207, 209–214, 215–217.

APPENDIX II

A SELECTION OF LECTURES AND BROADCASTS GIVEN BY MEMBERS OF THE STAFF

ALLEN, J. J.
Meteorology for yachtsmen. *Course of four lectures at the Adult Further Education Centre, Fleet.* January to March.

AUSTIN, J.
The influence of planetary waves on the stratospheric winter circulation. *Ninth Meeting of the European Geophysical Society, University of Leeds.* 26 August.

BROMLEY, R. A.
Modern methods of weather prediction. *Bath and Chippenham Area of the Institution of Electrical Engineers.* October.

BROOMFIELD, C. S.
Discussion of 'Cloud Types for Observers' (Met O 716). *Thames Valley Radio (Radio 210).* 14 September.

BROWN, R.
Meteorological Office cloud physics instrumentation. *Cloud Particle Measurement Symposium, Boulder, Colorado.* 4–7 May.
Studies of stratocumulus and radiation fog. *Air Force Geophysics Laboratory, Hanscombe Air Force Base, USA,* 10 May.

BROWNING, K. A.
Severe thunderstorms. *The Gaskell Memorial Lecture, Royal Meteorological Society, Manchester Centre.* 26 January.
A new approach to weather forecasting. *Cambridge Philosophical Society.* 25 October.
Air motion and precipitation growth in the major snowstorm of 8–9 January 1982. *Royal Meteorological Society, London.* 17 November.

BROWNSCOMBE, J. L.
Long-term monitoring of stratospheric temperature. *Remote Sensing Society Conference, Liverpool.* 15–17 December.

BRYANT, G. W.
Microfilm computer output in the Meteorological Office. *Lecture to British Computer Society, London.* 8 June.

CARSON, D. J.
The role of sea surface temperatures in seasonal prediction by dynamical methods. *Second meeting of the contact group, Climate Modelling, of the EEC Climatology Research Programme, Brussels.* 11 May.

CAUGHEY, S. J.
Interview on functions of Belfast Weather Office. *'Day to Day' program.* 25 November.

CLOUGH, S. A.
Results of some Stratospheric Sounding Unit analyses. *Workshop on comparison of data and derived dynamical quantities during northern hemisphere winters of Pre-Middle Atmosphere Program Project*—1 (1979–82), Boulder, Colorado. 11 May.

Simulations of an observed stratospheric warming with quasigeostrophic refractive index as a model diagnostic. *Royal Meteorological Society Meeting on Sudden Warmings, London.* 20 October.

COCHRANE, J.

Can the Meteorological Office help? *ADAS Land and Water Services Course on Farm Crop Storage, Shuttleworth College, Old Warden.* 4 January.

Diseases and spraying. *Arable Group, Market Bosworth.* 21 January.

The current state of Pea moth and Cut worm forecasts. *ADAS Entomologists Technical Conference, Cambridge.* 21 July.

COLLIER, C. G.

The use of Meteosat image data combined with radar data in the UK. *European Space Operations Centre, Darmstadt, Federal Republic of Germany.* 20 January.

CORNFORD, S. G.

Greenhouses, satellites and weather. *Kew Mutual Improvement Society.* 15 March.

Introduction of meteorology in secondary schools. *Symposium on Education and Training in Meteorology, WMO Education and Training Programme, Costa Rica,* 6–10 December.

CRABTREE, J.

Meteorology, nuclear, biological and chemical warfare. *Scientific Advisers' Advanced Course, Defence, Nuclear, Bilogical and Chemical Centre, Winterbourne Gunner, Wilts.* 8 June.

Studies of plume transport and dispersion over distances of travel up to several hundred kilometres. *NATO/CCMS 13th International Technical Meeting, Toulon, France.* 14 September.

CULLEN, M. J. P.

Finite element methods for the Navier–Stokes equations.

Mathematics Department, Imperial College, London, 27 January.

Mathematics Department, University of Reading, 17 March.

Institute of Mathematics and its Applications Conference on Numerical Methods in Fluid Dynamics, Reading. 30 March.

Numerical treatment of some discontinuities in the atmosphere.

Computing Laboratory, University of Oxford. 4 November.

Heriot-Watt University, Edinburgh. 26 November.

DICKINSON, A.

Vector processors versus IBM 360/195 performance. *Conference on Atmospheric and Oceanographic Applications, Boulder, Colorado.* 11 February.

UK Meteorological Office experience in programming the new analysis system and forecast model on the CYBER 205.

Geophysical Fluid Dynamics Laboratory, Princeton, USA. 16 February.

Goddard Laboratory for Atmospheric Sciences, Washington, USA. 18 February.

National Meteorological Center, Washington, USA. 18 February.

The role of the super computer in numerical weather prediction. *Control Data Seminar on the CYBER 205, Piccadilly Hotel, London.* 16 June.

Precipitation forecasts at the UK Meteorological Office. *European Working Group on Limited Area Modelling, Météorologie Nationale, Paris.* 6 October.

DIXON, J.

Role and function of the sector forecaster. *Sector Scientific Advisers Course. Home Defence College, Easingwold.* 27 July.

EASTWOOD, P. J.

Interview on activities of new Belfast Weather Office. '*Downtown*' *radio program.* 25 November.

ECCLESTON, A. J.

Short-period weather forecasting. *School of Maritime Studies, Plymouth Polytechnic.* 27 January.

The work of the Meteorological Office Radar Research Laboratory. *International Conference of Hydrological Scientists, Giffard Hotel, Worcester.* 31 July.

Digital mapping and remote sensing—meteorological applications. *1982 Seminar, Royal Society, London.* 18 October.

The use of Meteosat imagery and a network of radars for observing and forecasting rainfall. *Remote Sensing Society Conference, Liverpool.* 15 December.

EYRE, J. R.

Local area temperature sounding from satellites. *Seminar at Department of Atmospheric Physics, University of Oxford.* 2 December.

FIELD, M.

The Meteorological Office Rainfall and Evaporation Calculation System—MORECS. *Ninth Meeting of the European Geophysical Society, University of Leeds.* 25 August.

FLOOD, C. R.

Applications to forecasting of the proposed remote sensing program of the European Space Agency. *Royal Society, London,* January.

Numerical model output for aviation. *Société Internationale de Télécommunications Aéronautiques, Paris.* October.

FOLLAND, C. K.

Interdecadal variations of quasi-global sea surface temperature.

Department of Geological Sciences, Brown University, Rhode Island, USA. 6 December.

Department of Meteorology and Physical Oceanography, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA. 7 December.

National Climate Research Program Office, Rockville, Maryland, USA. 10 December.

FORRESTER, D. A.

The atmosphere and wind dangers to aircraft. *Flight Safety Discussion Group Meeting, London.* 1 December.

FUGARD, T. B.

The Poisson representation of distributions. *Function Theory Day, Open University, Milton Keynes.* 27 September.

GILCHRIST, A.

Increased carbon dioxide concentrations and climate: The equilibrium response. *International School of Climatology, Erice, Sicily.* 20 July.

Aspects of the simulation of climate and climate variability in middle latitudes. *Main Geophysical Observatory, Leningrad, USSR.* 13 September.

Experiments on long-range prediction. *Geophysical Fluid Dynamics Laboratory, Princeton, USA.* 3 December.

GLOSTER, J.

Airborne spread of foot-and-mouth disease. *Veterinary Research Club, London.* 12 March.

The 1982 outbreaks of foot-and-mouth disease—Denmark and German Democratic Republic. *Members of L'Office International des Epizootics, Animal Virus Research Establishment, Pirbright.* 22 September.

GOLDSMITH, P.

The status of weather modification. *Presidential Address to Royal Meteorological Society, London.* 16 June.

Recent visibility trends in the United Kingdom. *Joint Meeting of Royal Meteorological Society and Hellenic Meteorological Society, Keble College, Oxford.* 1 September.

HIDE, R.

On the role of rotation in the generation of magnetic fields by fluid motions. *Royal Society Discussion Meeting, London.* 28 January.

Rotating fluids in geophysics and planetary physics.

University of Bristol. 11 March.

Ninth Meeting of the European Geophysical Society, University of Leeds. 24 August.

University of Grenoble. 9 September.

Giant planets. *Holweck Prize Lecture, Societe Française de Physique, Paris.* 11 June.

Geomagnetic secular variation. *Ninth Meeting of the European Geophysical Society University of Leeds.* 23 August.

HIGNETT, P.

Two lectures: (1) Intransitivity and vacillation in a differentially heated rotating fluid annulus, (2) Axisymmetric thermal convection in a rotating fluid. *Ninth Meeting of the European Geophysical Society, University of Leeds.* 25 August.

HOUGH, M. N.

Wind, plastic and weedkiller. *Royal Meteorological Society, North-east Centre, Durham.* 12 February.

Crop development in operational models. *Cereal Unit, National Agricultural Centre, Stoneleigh.* 24 February.

Weather and farming. *Tyne-Tees Television, 'Farming Outlook'.* 27 June.

JENKINS, G. J.

Air pollution meteorology. *Centre for Computational Mechanics, Southampton.* 17 May.

Dispersion meteorology. *Scientific Advisers' Course, Defence, Nuclear, Biological and Chemical Centre, Winterbourne Gunner, Wilts.* 7 June.

Weather science and weather forecasting. *Royal Meteorological Society Field Studies Course, Nettlecombe, Somerset.* 25–31 August.

Airships and meteorology. *History of Meteorology Meeting, Royal Meteorological Society, Bracknell.* 9 October.

JERRETT, D.

High resolution soundings of atmospheric temperature in the European North Atlantic area. *Remote Sensing Society Conference, Liverpool.* 15–17 December.

JONAS, P. R.

Time-series analysis of thermally driven rotating flows in an annulus. *Mathematics Department, University College, London.* 19 February.

JONES, D. E.

Large-scale circulation features during the 1981–82 winter. *Discussion Meeting, Royal Meteorological Society, London.* 17 November.

Long-range forecasting and climate change. *Interview, BBC Radio, Scotland.* 3 December.

KING, J. C.

A numerical study of two-dimensional eddies in the stable atmospheric boundary layer. *Twenty-fourth British Theoretical Mechanics Colloquia, The City University, London.* 2 April.

LAWSON, J.

Role of the meteorologist in the UK Warning and Monitoring Organization. *Royal Observer Corps No. 15 Group, Lincoln.* 26 October

LITTLE, C.
Objective analysis at the UK Meteorological Office. *Symposium on Numerical Prediction, Geneva.* 28 September.
LORENC, A. C.
The impact of aircraft data on the Meteorological Office FGGE data assimilation suite. *Joint Scientific Committee Study Conference on Observing Systems Experiments, Exeter.* 22 April.
On direct data assimilation into a forecast model.
Fourteenth Stanstead Seminar, Lennoxville, Canada. 16 July.
National Meteorological Center, Washington. 20 July.
A case study comparison of UK Meteorological Office, ECMWF and National Meteorological Center analyses. *National Meteorological Center, Washington.* 22 July.
LUNNON, R. W.
Predictability and long-range weather forecasting. *Ninth Meeting of the European Geophysical Society, University of Leeds.* 23–27 August.

MANSFIELD, D. A.
The use of dynamical models in long-range weather forecasting. *Ninth Meeting of the European Geophysical Society, University of Leeds.* 23–27 August.
The use of general circulation models in long-range forecasting. *Colloquium, Atmospheric Physics Group, Imperial College, London.* 25 November.
MASON, SIR JOHN
The carbon dioxide problem—global implications. *Parliamentary Liaison Group for Alternative Energy Strategies, House of Lords.* 8 March.
Numerical modelling of weather and climate using giant computers. *Society for the Application of Research, University of Cambridge.* 5 April.
Man's attempts to modify the weather. *Culham Laboratory, Abingdon, Oxfordshire.* 11 June.
Use of radar and satellites for short-range weather forecasting. *WMO, Eighth Session of Regional Association VI (Europe), Rome.* 9 October.
MASON, P. J.
Trailing vortices induced by surface-mounted obstacles.
Twenty-fourth British Theoretical Mechanics Colloquium, The City University, London. 1 April.
European Mechanics Colloquium 163, Lisbon, Portugal. 8 November.
Observations of wind flow over hills. *Wind Engineering Research Group, Building Research Establishment, Garston, Herts.* 21 April.
MAY, B. R.
Snowmelt advice from the Meteorological Office. *Conference of River Engineers, Cranfield.* 6 July.
MITCHELL, J. F. B.
Simulations with UK Meteorological Office 5-layer and 11-layer models. *ECMWF Workshop on Intercomparison of Large-scale Models used for Extended Range Forecasts, Reading.* 30 June.
The use of general circulation models in climate modelling. *Ninth Meeting of the European Geophysical Society, University of Leeds.* 26 August.
Meteorological Office research on carbon dioxide and climate. *Carbon Dioxide, Science and Consensus, US Department of Energy, West Virginia.* 21 September.
MOORE, J. G.
Our weather, '*Exploring Earth*' series. *BBC Schools Radio.* January.

NASH, J.

High precision observations of radiative temperature from stratospheric sounding units. *Seminar at Department of Atmospheric Physics, University of Oxford.* 11 March.

Validation of Stratospheric Sounding Unit. *COSPAR, Ottawa.* 28 May.

NEWMAN, M. R.

GCM simulations of the monsoon onset. *Royal Meteorological Society Dynamical Problems Subgroup Meeting, Meteorological Office College, Reading.* 16 November.

NICHOLLS, S.

The structure of the turbulent atmospheric boundary layer. *Results of the Royal Society Joint Air–Sea Interaction Project (JASIN), The Royal Society, London.* 2 June.

OFFILER, D.

Two lectures: (1) SEASAT wind scatterometer, (2) SEASAT radar altimeter. *Summer School on Remote Sensing Applications in Marine Science and Technology, University of Dundee.* 9–13 August.

O'NEILL, A.

The mutual interaction of planetary waves and the mean flow in the stratosphere. *University of Reading.* 30 April.

OULDRIDGE, M.

Simultaneous measurements of rain by airborne disdrometer and dual polarization radar. *Symposium on Multiple Parameter Radar Measurement of Precipitation, Bournemouth.* 24 August.

PALLISTER, R. C.

The upper stratospheric diurnal variation of ozone as a test of photochemical theory. *Ninth Meeting of the European Geophysical Society, University of Leeds.* 25 August.

PALMER, T. N.

Sudden stratospheric coolings and wave propagation on a zonally asymmetric basic state.

University of Washington, Seattle. 26 February.

National Center for Atmospheric Research, Boulder, Colorado. 22 September.

Harvard University. 28 September.

Simulations of an observed stratospheric warming with quasigeostrophic refractive index as a model diagnostic.

National Center for Atmospheric Research, Boulder, Colorado. 21 September.

Goddard Space Flight Center, NASA. 23 September.

PARTINGTON, S. J. G. and DEMPSTER, B. J.

Interview on day-to-day activities of Belfast Weather Office. *'All in a Day's Work' program, BBC.* 19 November.

Interview on functions of new Belfast Weather Office and the weather station on the roof of Progressive House. *'Scene Around Six' program, BBC Television.* 25 November.

PURSER, J. M.

Mesoscale analysis at the UK Meteorological Office. *Workshop on Current Problems in Data Assimilation, Reading.* 8 November.

READ, P. L.

Baroclinic eddies in an internally heated fluid annulus. *Royal Meteorological Society Discussion on Planetary Atmospheres, London.* 20 January.

Baroclinic eddies in the laboratory and in the atmospheres of Jupiter and Saturn. *Ninth Meeting of the European Geophysical Society, University of Leeds.* 26 August.
University College, London. 12 November.

RIDDAWAY, R. W.
Use of the computer in weather forecasting. *British Computer Society, Glasgow Branch.* 25 January.
Series of 42 twenty-minute talks. *Physics at Work Exhibition, Hatfield Polytechnic.* 13–15 July.
Weather forecasting today. *Senior Schools Lecture, Royal Meteorological Society, Scottish Centre.* 29 October.

ROACH, W. T.
Possible physical causes of the extremely low screen temperatures in the west Midlands during the 1981–82 winter. *Royal Meteorological Society Meeting, London.* 17 November.

ROE, C. P.
Weather and agriculture. *Reading Young Farmers' Club.* 16 February.

ROWNTREE, P. R.
The effects of soil moisture and land surface albedo in general circulation models. *COSPAR Sahel Workshop, Paris.* 28 January.
Atmospheric modelling studies relevant to the Southern Oscillation. *Royal Meteorological Society Meeting, London.* 21 April.
Interview on the possible role of soil moisture and albedo in Sahel droughts. *BBC African Service, 'Blueprint Africa'.* 12 May.
Some aspects of the sensitivity of general circulation models to land surface processes. *ECMWF Workshop on Intercomparison of Large-scale Models used for Extended Range Forecasts, Reading.* 1 July.
Modelling of the Southern Oscillation and related phenomena. *USA National Research Council, El Nino/Southern Oscillation Study Conference, Geophysical Fluid Dynamics Laboratory, Princeton University.* 13 October.

RYDER, P.
Physics of thunder and lightning. *University of Wales Institute of Science and Technology, Swansea.* 25 February.

SHUTTS, G. J.
Eddy fluxes and blocking. *Atmospheric Physics Group, Imperial College, London.* 9 December.

SLINGO, A.
Case studies of radiation in the atmospheric boundary layer. *Results of the Royal Society Joint Air–Sea Interaction Project (JASIN), The Royal Society, London.* 3 June.

SMITH, C. J.
The Meteorological Office weather radar network. *Department of Electrical and Electronic Engineering, University of Bradford.* 12 October.

SMITH, C. V.
Two lectures: (1) The role of climatological information in the protection of plants and animals, (2) Climatological aspects of in-harvest and post-harvest losses. *Technical Conference on Climate—Africa, Arusha, Tanzania.* 25–30 January.

SMITH, F. B.
Diffussion of pollution in the atmosphere. *University of Surrey, Guildford.* 4, 11 and 18 February.
Current work of the Boundary Layer Branch of the Meteorological Office. *University of Naples, Italy.* 15 March.
The long-range transport of pollution. *Open lecture at the Meteorological Office, Edinburgh.* 5 May.

The equation of diffusion. *NATO/CCMS Thirteenth International Technical Meeting, Toulon, France.* 14 September.
The acid rain problem. *Royal Meteorological Society, London.* 15 December.

SPACKMAN, E. A.
This winter's weather in perspective. *Brussels Sprout Open Day, Northill, Bedford.* 26 January.
The use of meteorological data in cereal management of crop water supply. *Arable Crops Single Discipline Group, Writtle College of Agriculture.* 22 September.
Spray occasions analysis 1981–82. *British Crop Protection Herbicide Review 1982, London.* 27 October.

SPARKS, W. R.
Weather and crop growth. *West Somerset Agricultural Club.* 19 November 1981.
Weather and cereals production. *ADAS Conference on Soil Care for Cereals, Andersford.* 25 January.
Development of a miniature weather recording station. *Conference on Cereal Diseases—Planning for Better Control, National Agricultural Centre, Stoneleigh.* 10 February.

STARR, J. R.
Meteorological services for farmers. *National Farmers Union, Horsham Branch.* 14 January.
Flukes, frosts, calves and crops.
University of Reading Physical Society. 28 January.
Chichester College of Technology. 3 March.
British Association for the Advancement of Science (Youth Section), University of Southampton. 15 March.
Weather on the farm. *Women's Institute, Warfield Branch.* 9 February.
Weather for horticulturalists. *Norwood Hall College, Southall.* 11 February.
Animals and weather—pestilence, plague and productivity. *The Margary Lecture, Royal Meteorological Society, Imperial College, London.* 17 February.
Meteorological services for agriculture. *OND III Course, Sparsholt College.* 15 March.
Agricultural meteorology in the UK Meteorological Office. *Postgraduate Students, University of Reading.* 24 March.
Interview on lamb wind-chill. *BBC Radio Oxford.* 5 April.
Interpreting weather data. *Wessex Cereal Group, Bridgets Experimental Husbandry Farm, Winchester.* 9 September.
Weather and the dairy industry. *National Institute for Research in Dairying, Reading.* 2 November.
Agricultural meteorology. *South-east Agricultural Advisory Officers Conference, Bournemouth.* 19 November.

TEMPERTON, C.
Variational normal mode initialization for the ECMWF grid-point model. *Fourteenth Stanstead Seminar, Lennoxville, Canada.* 15 July.
Problem of multiple time scales in numerical weather prediction. *Meeting on Problems in Multi-time Scale Dynamics, Centre Européen de Calcul Atomique et Moleculaire, Ommen, Netherlands.* 12 October.

THOMPSON, N.
Weather and agriculture.
Sherborne School. 5 February.
Great Shefford Young Farmers Club. 12 October.
Meteorology as an aid to crop protection. *British Crop Protection Council Symposium on Decision Making in the Practice of Crop Protection, Brighton.* 6 April.
Agricultural meteorology. *Hartley Wintney Young Farmers Club.* 27 April.

The Meteorological Office Rainfall and Evaporation Calculation System. *Department of Civil Engineering, Imperial College, London.* 11 May.

Meteorological aspects of spray drift. *Department of Meteorology, University of Reading.* 28 May.

Meteorology and farming. *East Berkshire College of Agriculture.* 21 September.

The quantification of spray drop drift. *British Crop Protection Council Conference—Weeds, Brighton.* 25 November.

TUCK, A. F.

The transport of water vapour in a stratosphere–troposphere general circulation model. *Ninth Meeting of the European Geophysical Society, University of Leeds.* 26 August.

TURNER, J.

Experience of using a CYBER 205 computer for operational applications in meteorology. *Colorado State University, Fort Collins.* August.

VAUGHAN, G.

Dulliau cyfoes o ragweld y tywydd (Modern methods of weather forecasting). *Clwyd Scientific Society, St Asaph,* 1 October.

WASS, S. N.

Weather and glass. *Somerset Glasshouse Growers Club.* 2 March.

Weather and grass production in Somerset and Devon. *ADAS Divisional Staff Training Meeting, Taunton.* 28 April.

WHITE, A. A.

Approximate non-linear formulations in geophysical fluid dynamics. *University College, London.* 19 February.

Thermal convection in a rotating baroclinic fluid—laboratory and numerical studies of baroclinic waves. *Ninth Meeting of the European Geophysical Society, University of Leeds.* 25 August.

WICKHAM, P. G.

Forecasting methods. *Six lectures at a course for M.Sc. students, Department of Meteorology, University of Reading.* February–March.

Two lectures: (1) Basic meteorology, (2) Weather forecasting. *Scientific Advisers' Course, Defence, Nuclear, Biological and Chemical Centre, Winterbourne Gunner, Wilts.* 7–8 June.

WILEY, R. L.

The role of satellites in weather forecasting. *Institution of Electrical Engineers, London.* 6 October.

YOUNG, M. V.

Applications of mathematics in meteorology. *Manchester Polytechnic.* 12 April.

APPENDIX III

INTERNATIONAL MEETINGS ATTENDED BY MEMBERS OF THE STAFF

The more important meetings are discussed in the report of the International and Planning Branch on pages 62–65. Attendances at WMO meetings, or joint WMO meetings with other international bodies, were as follows:

Title	*Place and date*	*Attended by*
Technical Conference on Climate in Africa	Arusha Tanzania January	Mr C. V. Smith, AD Met O (AH)*
Commission for Atmospheric Sciences—8th session	Melbourne February	Dr K. H. Stewart, Director of Research
Informal Planning Meeting of Major Donor Members to the VCP	Geneva March	Mr G. J. Day, AD Met O (IP)
WMO/UNEP Governmental Expert Meeting on Climate-related Monitoring	Geneva March	Dr A. F. Tuck (Met O 15)
WMO/EPPO Symposium on Meteorology and Plant Protection	Geneva March	Mr W. A. Sparks (Met O 8)
RA VI Working Group on Meteorological Telecommunications—13th session	Geneva March/April	Mr A. I. Johnson, AD Met O (TC)
Scientific and Technical Advisory Committee—3rd session	Geneva March/April	Mr G. J. Day, AD Met O (IP)
Consortium of Contributors to ASDAR Development Fund	Geneva April	Mr G. J. Day, AD Met O (IP)
EC Working Group on Antarctic Meteorology	Geneva April	Mr G. J. Day, AD Met O (IP)
JSC Working Group on Numerical Experimentation—3rd session	Exeter April	Mr F. H. Bushby, Director of Services Mr A. Gilchrist, DD Met O (D)*
Study Conference on Observing System Experiments	Exeter April	Mr F. H. Bushby, Director of Services Mr A. Gilchrist, DD Met O (D) Miss M. J. Atkins (Met O 2) Mr A. C. Lorenc (Met O 20)
Commission for Climatology and Applications of Meteorology—8th session	Washington, D.C. April	Mr F. Singleton, AD Met O (CS)
ICAO Communications/Meteorology Divisional Meeting (1982)/CAeM Conjoint Session, and 7th session of the WMO Commission for Aeronautical Meteorology	Montreal April/May	Mr D. H. Johnson, DD Met O (F) Mr K. Bryant (Met O 7) Mr R. J. Sowden (Met O 5)
CAgM Working Group on Weather and Animal Health	Geneva May	Mr C. V. Smith, AD Met O (AH)
CBS Working Group on Codes—6th session	Geneva May	Mr R. J. Sowden (Met O 5)

*The full titles of the Deputy Directors (DDs) and the Assistant Directors (ADs) are given on pages ix–xi. Other abbreviations are explained in Appendix V (pages 167–168).

Title	*Place and date*	*Attended by*
Preparatory Committee of the Executive Committee	Geneva June	Mr G. J. Day, AD Met O (IP) Mr M. W. Stubbs (Met O 17)
Thirty-fourth session of the Executive Committee	Geneva June	Sir John Mason, Director-General Mr G. J. Day, AD Met O (IP) Mr M. W. Stubbs (Met O 17)
Study Group of CBS Working Group on Data Transmission Techniques	Geneva June/July	Mr R. J. Sowden (Met O 5)
North Atlantic Ocean Stations—7th session of the Board	Geneva July	Dr D. N. Axford, DD Met O (O) Captain G. A. White, Marine Superintendent Mr J. R. Hughes (Met O 4)
EMEP Meeting on Long-range transport of air pollution	Leatherhead July	Dr F. B. Smith (Met O 14) Mr J. Crabtree (Met O 14)
CBS Working Group on the Global Telecommunication System—10th session	Geneva July	Mr A. I. Johnson, AD Met O (TC)
Preparation of 2nd Draft of WMO Guide on Automation of Data-processing Centres	Geneva July	Mr M. W. Stubbs (Met O 17)
Working Group for the Review of the Long Term Plan	Geneva August	Mr G. J. Day, AD Met O (IP)
Study Conference on the Physical Basis of Climate Prediction on Seasonal, Annual and Decadal Time Scales	Leningrad September	Mr A. Gilchrist, DD Met O (D)
Informal Meeting of Experts on the Development of the Programme for Weather Prediction Research Study Projects	Reading September	Dr P. W. White, AD Met O (FR)
Study Group on Marine Meteorological Services of the CMM Working Group on MMS	Geneva September	Captain G. A. White, Marine Superintendent
Symposium on Building Climatology	Moscow September	Mr M. J. Prior (Met O 3)
Regional Association VI (Europe)—8th session	Rome October	Sir John Mason, Director-General Mr M. J. Blackwell, DD Met O (C) Mr G. J. Day, AD Met O (IP) Mr C. R. Flood, AD Met O (CF)
EC Panel of Experts on Weather Modification/CAS Working Group on Cloud Physics and Weather Modification	Geneva October	Mr P. Goldsmith, Director of Research
Revision of WMO Manual on Marine Meteorological Services and Marine Climatological Summaries	Geneva October	Mr R. J. Shearman (Met O 3)
Session of the Study Group on the Guide on the GDPS of the CBS Working Group on GDPS	Geneva November	Miss M. J. Atkins (Met O 2)
Regional Association I (Africa)—8th session	Cairo November	Mr M. W. Stubbs (Met O 17)
Drafting of the Ocean Wave Programme	Geneva November/December	Dr P. E. Francis (Met O 2)
First session of WMO Interim Committee of ASDAR Participants	Geneva December	Mr G. J. Day, AD Met O (IP)

Title	*Place and date*	*Attended by*
Programme Board of Consortium for ASDAR Development (CAD)	Geneva December	Mr G. J. Day, AD Met O (IP)
Expert Study Meeting on Long-range Forecasting	Princeton, N.J. December	Mr A. Gilchrist, DD Met O (D)
JSC Working Group on Numerical Experimentation—4th session	Princeton, N.J. December	Mr A. Gilchrist, DD Met O (D)
World-wide Symposium on Education and Training in Meteorology with emphasis on Climatic Change and Variability	San José Costa Rica December	Mr S. G. Cornford, AD Met O (PT)

Attendances not already listed, at international conferences sponsored wholly or primarily by bodies other than WMO, and other visits abroad, were as follows:

Subject/purpose	*Place and date*	*Attended by*
Symposium on Vector Processing for Atmospheric and Oceanographic Applications	Boulder, CO January	Dr A. Dickinson (Met O 11)
Offshore Industry Exploration and Production Forum	London January, April	Mr R. M. Morris, AD Met O (PS)
ICAO HELIMET Working Group of METAG	Paris January	Mr B. D. Hunt (Met O 7)
ESA Scientific and Technical Advisory Group to Meteorological Satellite Programme Board	Darmstadt January	Mr D. E. Miller, AD Met O (SM) Mr C. G. Collier (Met O RRL)
Meteosat Operations Advisory Group	Darmstadt January	Mr D. E. Miller, AD Met O (SM)
Discussions with ESA on Active Microwave Pressure Sounder	Paris January	Dr D. R. Pick (Met O 19)
ESA Scatterometer Experts Group	Hamburg January	Mr D. Offiler (Met O 19)
MCMG Working Group on Weather Communications	Traben-Trarbach January	Mr C. E. Goodison (Met O 5)
COSPAR Workshop on Climate Fluctuations in the Sahel	Paris January	Dr P. R. Rowntree (Met O 20)
COST Senior Officials Meeting	Brussels February	Dr R. E. W. Pettifer, AD Met O (OI)
Offshore Safety Congress	Eastbourne February	Mr R. M. Morris, AD Met O (PS)
Commission of European Communities, Project F, Radiation on Inclined Surfaces	Reading February	Mr F. Rawlins (Met O 1)
International Energy Agency Solar Energy Programme, Meeting on Pyranometry	Davos February	Mr J. Seymour (Met O 1)
IMCO Sub-committee on Safety of Navigation—26th session	London February	Captain G. V. Mackie, Marine Division
NASA/Upper Air Research Satellite Team Meeting	Greenbelt, MD February	Dr A. J. Gadd, AD Met O (DC)
ECMWF Finance Committee—27th session	Reading March	Mr G. J. Day, AD Met O (IP) Mr M. W. Stubbs (Met O 17)
Eurocontrol Experimental Centre, discussion on the use of aircraft derived data	Paris March	Dr D. A. Forrester (Met O 9)

Subject/purpose	*Place and date*	*Attended by*
Visit to the National Advanced Systems Corporation	San Francisco, CA March	Dr W. A. McIlveen (Met O 22)
IMA Conference on Numerical Methods in Fluid Dynamics	Reading March	Dr M. J. P. Cullen (Met O 11)
Site inspection for ATD Sferics equipment	Gibraltar March	Mr M. Collins (Met O 16)
Oceanology International Conference	Brighton March	Mr R. M. Morris, AD Met O (PS)
Discussion on the participation of the Meteorological Service of the Republic of Ireland in the Radar Network	Shannon, Republic of Ireland March	Mr C. G. Collier (Met O RRL) Mr W. R. Timms (Met O RRL)
NATO MCMG Ad hoc Group	Norfolk, VA March	Mr I. J. W. Pothecary, AD Met O (DS)
ESA Programme Board Meeting	Paris March	Dr K. H. Stewart, Director of Research
Visits to the Australian Bureau of Meteorology and the Numerical Meteorology Research Centre	Melbourne March	Miss M. J. Atkins (Met O 2)
Visit to the New Zealand Meteorological Service	Wellington March	Miss M. J. Atkins (Met O 2)
Visit to the National Meteorological Centre	Washington, D.C. March	Mr C. R. Flood, AD Met O (CF)
Visit to the National Weather Service	Silver Springs, MD March	Mr C. R. Flood, AD Met O (CF)
Visit to the Fleet Numerical Oceanography Centre	Monterey, CA March	Mr C. R. Flood, AD Met O (CF)
ESA Scatterometer Experts Group	Toulouse March	Mr D. Offiler (Met O 19)
NOAA National Earth Satellite Service, discussions on satellite instruments	Washington, D.C. March	Dr D. R. Pick (Met O 19)
Inspecting technical equipment	Germany March/April	Mr P. J. Collins (Met O 16)
Twelfth Informal Conference of Directors of European Meteorological Services	The Hague April	Sir John Mason, Director-General
European Working Group on Observing Systems Experiment	Exeter April	Mr A. Gilchrist, DD Met O (D)
ECMWF Council, 15th session	Reading April	Sir John Mason, Director-General Mr G. J. Day, AD Met O (IP) Mr J. E. McNulty, Head of Met O 4
ICAO North Atlantic Systems Planning Group	Paris April	Mr R. M. Morris, AD Met O (PS)
European CDC Users Group	Minneapolis, MN April	Dr S. R. Mattingly (Met O 12)
EEC Contractors Meeting on Wind Energy Project	Risø, Denmark April	Mr R. J. Shearman (Met O 3)
NATO MCMG Working Group on Weather Plans and Weather Communications, 55th session	Brussels April	Mr C. E. Goodison (Met O 5) Dr J. I. Gibbs (Met O 6)
NATO 30th AFCENT Meteorological Committee	Cologne April	Mr J. Keers (Met O 6) Mr D. G. Strachan (Met O 6) Mr M. G. Waller (Met O 6)
Visit to the Geophysical Fluid Dynamics Laboratory	Princeton, N.J. April	Mr C. R. Flood, AD Met O (CF)

Subject/purpose	Place and date	Attended by
Meteosat Operations Advisory Group	Darmstadt April, July, Octo er	Mr J. Morgan (Met O 19)
Cloud Particle Measurement Symposium	Boulder, CO May	Mr R. Brown (Met O 15)
Geophysics Laboratory, Hanscombe Air Force Base	Boston, MA May	Mr R. Brown (Met O 15)
Inspecting technical equipment	Cyprus May	Mr P. J. Collins (Met O 16)
IBM User Group	Noordwykerhout, Netherlands May	Mr M. J. Phillips (Met O 12)
EEC Contact Group on Climate Modelling	Brussels May	Dr A. Slingo (Met O 20) Dr D. J. Carson (Met O 13)
Defence Quadripartite Working Group	Woolwich May	Mr P. G. Rackliff (Met O 6)
First International Conference on Meteorology and Air/Sea Interaction of the Coastal Zone	The Hague May	Dr P. E. Francis (Met O 2)
Committee on Space Research (COSPAR) Conference	Ottawa May	Dr J. Nash (Met O 1) Dr T. N. Palmer (Met O 20)
Comparison of stratospheric data and derived dynamical quantities	Boulder, CO May	Dr S. A. Clough (Met O 20) Dr T. N. Palmer (Met O 20)
ECMWF Technical Advisory Committee—4th session	Reading June	Mr D. H. Johnson, DD Met O (F) Dr R. L. Wiley, AD Met O (SM)
Royal Society discussion meeting on JASIN	London June	Dr P. R. Jonas, AD Met O (CP) Mr R. Brown (Met O 15) Mr S. Nicholls (Met O 15) Dr G. J. Jenkins (Met O 1) Dr A. Slingo (Met O 20)
ECMWF Scientific Advisory Committee	Reading June	Mr F. H. Bushby, Director of Services
COST 43 Management Committee	Brussels June	Dr R. E. W. Pettifer, AD Met O (OI)
COST Senior Officials	Brussels June	Dr R. E. W. Pettifer, AD Met O (OI)
Incorporation of Shannon weather radar into the UK network	Dublin June	Dr D. N. Axford, DD Met O (O)
ESA Working Group on Atmospheric Instrumentation Definition Activities	Paris June, September	Mr D. E. Miller, DD Met O (P)
COST 72 Project	Stockholm June	Mr C. G. Collier (Met O RRL)
NATO CDC Working Group of Experts on Fallout Warning Exercises	Nainville-Les-Roches, France June	Mr P. G. Rackliff (Met O 6)
NATO 24th SHAPE Meteorological Committee	Mons, Belgium June	Mr D. Forsdyke (Met O 6)
ESA Active Microwave Instrument Experts Group	Toulouse June	Mr D. Offiler (Met O 19)
European Study Group on the Inversion of TIROS Operational Vertical Sounder Data	Bologna June	Dr J. R. Eyre (Met O 19)
NATO 39th MCMG and Ad Hoc Group	Traben-Trarbach June	Mr I. J. W. Pothecary, AD Met O (DS)
ECMWF Workshop on Intercomparison of Large-scale Models used for Extended-range Forecasts	Reading June/July	Dr D. J. Carson (Met O 13) Dr J. F. B. Mitchell (Met O 20) Dr P. R. Rowntree (Met O 20) Dr A. Slingo (Met O 20)

Subject/purpose	Place and date	Attended by
ESA Scientific and Technical Advisory Group to Meteorological Satellite Programme Board	Paris June, October	Mr J. Morgan (Met O 19)
ESA Meteorological Satellite Programme Board	Paris June, October, December	Dr R. L. Wiley, AD Met O (SM) Mr J. Morgan (Met O 19)
International School of Climatology	Erice, Sicily July	Mr A. Gilchrist, DD Met O (D)
Visit to HQ RAF Germany	Rheindahlen July	Sir John Mason, Director-General
NATO Advanced Study Institute on Meso-scale Meteorology	Chateau de Bonas, France July	Mr R. N. B. Smith (Met O 11)
Fourteenth Stanstead Seminar on Analysis and Initialisation of Atmospheric Observations	Lennoxville, Quebec July	Mr C. Temperton (Met O 11) Mr A. C. Lorenc (Met O 20)
Systems of Non-linear Partial Differential Equations	Oxford July	Dr M. J. P. Cullen (Met O 11)
Meteorological Support to NATO Early Warning Operations	Geilenkirchen July	Mr D. G. Strachan (Met O 6) Mr H. V. Foord (Met O 6)
Inspection visit and liaison with Commander British Forces and Civil Authorities	Cyprus July	Mr I. J. W. Pothecary, AD Met O (DS)
International Union of Radio Science Symposium on Multiple Parameter Radar Measurements of Precipitation	Bournemouth August	Mr M. Ouldridge (Met O 15) Dr P. K. James (Met O RRL)
Ninth European Geophysical Society	Leeds August	Dr D. A. Mansfield (Met O 13) Mr R. W. Lunnon (Met O 13) Dr A. F. Tuck (Met O 15) Mr R. C. Pallister (Met O 15) Mr J. Austin (Met O 15) Dr S. A. Clough (Met O 20) Dr A. O'Neill (Met O 20) Dr J. F. B. Mitchell (Met O 20) Dr R. Hide, Head of Met O 21 Dr P. L. Read (Met O 21) Dr P. Hignett (Met O 21) Dr A. A. White (Met O 21)
Symposium on Cyber 205 Applications	Fort Collins, CO August	Mr J. Turner (Met O 2)
Fifth Symposium on Computational Statistics	Toulouse August/September	Mr R. C. Tabony (Met O 3)
Meteosat Operational Programme Working Group, Sub-group on Institutional Matters	Paris September	Mr M. W. Stubbs (Met O 17)
ECMWF Finance Committee—28th session	Reading September	Mr G. J. Day, AD Met O (IP) Mr M. W. Stubbs (Met O 17)
Advisory Committee Programme Management, Climatology	Brussels September	Mr A. Gilchrist, DD Met O (D)
Discussions on the training of members of the Algerian National Meteorological Office in the UK	Algiers September	Mr S. G. Cornford, AD Met O (PT)
US Army Meso-meteorology Advisory Panel	Risø, Denmark September	Dr P. W. White, AD Met O (FR)
Numerical Prediction Seminar	Geneva September	Mr C. Little (Met O 11)

Subject/purpose	*Place and date*	*Attended by*
European Mechanics Colloquium on Coalescence and Deposition of Aerosol Particles	London September	Dr P. R. Jonas, AD Met O (CP)
European CDC Users' Group	Aalborg, Denmark September	Mr P. Graystone, AD Met O (DP) Dr S. R. Mattingly (Met O 12)
Offshore Industry Exploration and Production Forum	Bracknell September	Mr R. M. Morris, AD Met O (PS)
Seventh Meeting of ICAO METAG	Paris September	Mr K. Pollard (Met O 7)
Commission of European Communities, Project F, Solar Radiation	Copenhagan September	Mr J. Seymour (Met O 1)
Commission of European Communities, Project F, Radiation on Inclined Surfaces	Odeillo, France September	Mr F. Rawlins (Met O 1)
ESA Active Microwave Instrument Experts Group	Hamburg September	Mr D. Offiler (Met O 19)
NATO/CCMS 13th International Meeting	Toulon, France September	Dr F. B. Smith (Met O 14) Mr J. Crabtree (Met O 14)
NOAA National Earth Satellite Service discussions on satellite instruments	Madison, WI September	Dr D. R. Pick (Met O 19)
NATO 19th Army Armaments Group, Panel XII, Meteorology	Brussels September	Mr P. G. Rackliff (Met O 6)
NASA/UARS Science Team Meeting	Greenbelt, MD September	Dr A. J. Gadd, AD Met O (DC)
US Department of Energy Meeting on CO_2 Science and Consensus	Berkeley Springs, WV September	Dr J. F. B. Mitchell (Met O 20)
Meteosat Operational Programme Technical Sub-group	Paris September/October, December	Mr J. Morgan (Met O 19)
Inspection and calibration of Dobson Spectrophotometer	Singapore September/October	Mr J. M. Regan (Met O 15)
Meteosat Operational Programme Working Group	Paris September, November	Mr D. E. Miller, DD Met O (P) Mr J. Morgan (Met O 19)
Meteosat Operational Programme Working Group, Sub-group on Institutional Matters	Paris October	Mr M. W. Stubbs (Met O 17)
Scientific Programme Committee, Palaeoclimatic Research and Models Workshop	Brussels October	Mr A. Gilchrist, DD Met O (D)
European Working Group on Observing Systems Experiment	De Bilt October	Mr A. Gilchrist, DD Met O (D)
NATO CDC Working Group of Experts on Fallout Warning Exercises	London October	Mr P. G. Rackliff (Met O 6)
European Working Group for Limited Area Forecasting	Paris October	Dr A. Dickinson (Met O 11)
Problems in Multi-time scale Dynamics	Ommen, Netherlands October	Mr C. Temperton (Met O 11)
Electronics in Oil '82 Conference	London October	Mr R. M. Morris, AD Met O (PS)
ICAO Meeting on New Forecast Systems	Paris October	Mr B. D. Hunt (Met O 7)

Subject/purpose	*Place and date*	*Attended by*
Commission of European Communities, Project F, Solar Radiation	Brussels October	Dr G. J. Jenkins (Met O 1)
International Maritime Organisation Sub-committee on Safety and Navigation	London October	Captain G. A. White, Marine Superintendent
EEC Contractors Meeting on Wind Energy Project	Brussels October	Dr R. J. Adams (Met O 3)
Societé Internationale de Télécommunications Aéronautiques	Paris October	Mr C. R. Flood, AD Met O (CF)
ESA Active Microwave Instrument Experts Group	Amsterdam October	Mr D. Offiler (Met O 19)
NATO MCMG Working Group on Weather Plans and Weather Communications—56th session	Miami, FL October	Dr J. I. Gibbs (Met O 6) Mr C. E. Goodison (Met O 5)
Inspection and Liaison Visit	Gibraltar October	Mr A. Lambley (Met O 6)
Climate Research Committee/Ocean Sciences Board Study Conference on El Niño and the Southern Oscillation	Princeton, N.J. October	Dr P. R. Rowntree (Met O 20)
ECMWF Technical Advisory Committee Sub-group for Development of Computer Facilities	Reading October/November	Dr W. A. McIlveen (Met O 22)
ESA Experts Group on Data Handling for ERS–1 Satellite	Paris October, December	Mr J. Morgan (Met O 19)
ECMWF Council—16th session	Reading November	Sir John Mason, Director-General Mr G. J. Day, AD Met O (IP) Mr J. E. McNulty, Head of Met O 4
Inspecting technical equipment	Gibraltar November	Mr P. J. Collins (Met O 16)
European Mechanics Colloquium	Lisbon November	Dr P. J. Mason (Met O 14)
Workshop on Satellite Operational Temperature and Water-vapour Sounding	Abingdon November	Mr D. E. Miller, DD Met O (P) Mr A. C. Lorenc (Met O 20)
NATO MCMG Ad Hoc Group	London November	Mr I. J. W. Pothecary, AD Met O (DS)
ECMWF Workshop on Current Problems in Data Assimilation	Reading November	Mr A. C. Lorenc (Met O 20)
Liaison visits to certain Meteorological Services in RAI (Africa)	Africa November/ December	Mr. M. W. Stubbs (Met O 17)
International, Symposium on 'Milankovitch and Climate'	New York November/ December	Mr C. K. Folland (Met O 13)
Informal Workshop on Sea Surface Temperature Sensitivity Experiments	Princeton, N.J. December	Mr A. Gilchrist, DD Met O (D)
Symposium on the Impact of Cumulus Parametrization on Large-scale Numerical Weather Prediction	Tallahassee, FL December	Dr B. Golding (Met O 11)
COST 43 Sub-group for North Sea/ Baltic/Faeroe/Shetland Areas	Brussels December	Mr D. J. Painting (Met O 16)
COST 43 Management Committee	Brussels December	Dr R. E. W. Pettifer, AD Met O (OI) Mr D. J. Painting (Met O 16)

Subject/purpose	*Place and date*	*Attended by*
Wave Model Inter-comparison Planning Group	De Bilt December	Dr P. E. Francis (Met O 2)
ESA Active Microwave Instruments Experts Group	Alpbach, Austria December	Mr D. Offiler (Met O 19)
Meteosat Operational Programme Working Group, Sub-group on Institutional Matters	Paris December	Mr J. Morgan (Met O 19)
Meteosat Operational Programme Special Sub-group	The Hague December	Mr J. Morgan (Met O 19)

APPENDIX IV

PUBLICATIONS

Publications issued by the Meteorological Office appear either in the form of official Government publications, obtainable through the sales office or usual agents of Her Majesty's Stationery Office, or (more commonly nowadays) as departmental publications which may be obtained directly from the Meteorological Office. Catalogues of both these classes are available free on request.

The titles which follow are those that were completed during 1982; an asterisk indicates that the publication concerned was handled by HMSO. The final numbers within brackets are International Standard Book Numbers (ISBN), which provide positive identification of those items that bear them.

PERIODICAL

Annual

Annual Report on the Meteorological Office 1981 (0 11 400339 4)*
Introduction to the Monthly Weather Report, Vol. 96, 1979 (0 11 725809 1)*
Marine climatological summaries for the Atlantic Ocean E of 50°W, N of 20°N (microfiche), 1961 (0 86180 075 3), 1962 (0 86180 064 8), 1963 (0 86180 079 6)
Monthly and annual totals of rainfall for the United Kingdom, 1975 (0 86180 067 2), 1976 (0 86180 073 7), 1977 (0 86180 076 1)
Monthly Weather Report, annual summary, Vol. 96, 1979 (0 11 725810 5)*
Snow survey of Great Britain, 1980/81 (0 86180 066 4)

Quarterly

*Marine Observer**
Stratospheric charts for the Northern Hemisphere (microfiche), 1981 2nd quarter (0 86180 069 9), 3rd quarter (0 86180 074 5), 4th quarter (0 86180 082 6)
Stratospheric charts for the Southern Hemisphere (microfiche), 1980 4th quarter (0 86180 072 9)

Monthly

Anomaly maps (London Weather Centre)
Builders' Inclement Weather Summary (Nottingham Weather Centre)
Daily Weather Summary (Newcastle and NE England)
Degree days (Heathrow)
Full tabulation of anemograms (London Weather Centre)
Lincoln Weather Diary (Nottingham Weather Centre)
Lincoln Weather Summary (Nottingham Weather Centre)
*Meteorological Magazine**
Monthly analysis of rainfall during the working day (Manchester Weather Centre)
Monthly Supplement to the Daily Weather Summary (Newcastle and NE England)
Monthly Weather Report (January to September 1981)*
Monthly Weather Summary (Bristol Weather Centre)
Monthly Weather Summary (Central southern England)
Monthly Weather Summary (London)
Monthly Weather Summary (SE England)
Monthly Weather Summary (Southampton)
Monthly Weather Summary (Southern Sussex)
Monthly Weather Summary (UK)
Monthly Wind Summary (Bristol Weather Centre)
Rainfall analysis (London Weather Centre)
Relative humidity and vapour pressure at Abbotsinch
Sunshine tabulation (London Weather Centre)
Temperature at Abbotsinch
Watnall Weather Diary (Nottingham Weather Centre)
Watnall Weather Summary (Nottingham Weather Centre)

Fortnightly
Meteorological Office Rainfall and Evaporation Calculation System (MORECS)
Weekly
Daily Weather Summary (Manchester)
Degree days (Heathrow), weekly edition
Soil temperatures (St James's Park)
Ice charts (scale 1:10 million), North Atlantic (Wednesdays only)
Weekly Weather Summary (London)
Daily
Daily Remarks (London Weather Centre)
Daily Weather Summary (London Weather Centre)
Shipping Chart and Forecast (Glasgow Weather Centre)

SERIAL

Climatological Memorandum No. 103: *Averages and frequency distribution of humidity for Great Britain and Northern Ireland 1961–70* (revised (0 86180 086 9)

Climatological Memorandum No. 113: *The climate of Great Britain—An introduction to the series* (0 86180 070 2)

Climatological Memorandum No. 115: *The climate of Great Britain—Edinburgh, the Lothian region and Stirling* (0 86180 088 5)

Scientific Paper No. 39: *A comparative study of some single pole visibility sensors, the Meteorological Office Mk 4 transmissometer and estimates of visibility made by observers* (0 11 400330 0)

Southampton Weather Centre Memorandum No. 5a: *Analysis of wind direction and speed at Calshot 1960–1979* (revised)

OCCASIONAL

Cloud types for observers (0 11 400334 3)*

Handbook of meteorological instruments (2nd edition): Volume 4, *Measurement of surface wind* (0 11 400331 9); Volume 6, *Measurement of sunshine and solar and terrestrial radiation* (0 11 400336 X); Volume 7, *Measurement of visibility and cloud height* (0 11 400338 6)*

Tables of temperature, relative humidity, precipitation and sunshine for the world. Part III, *Europe and the Azores* (revision) (0 86180 090 7)

Leaflet No. 1: *Weather advice to the community* (1982 edition)

Leaflet No. 3: *Weather bulletins, gale warnings and services for the shipping and fishing industries* (1982 edition)

Leaflet No. 6: *Rules for rainfall observers* (1982 edition) (0 86180 087 7)

Services for agriculture (1982 edition)

APPENDIX V

ACRONYMS AND ABBREVIATIONS

ACEWEX	Allied Command Europe Weather Exchange
ACRE	Automatic Climatological Recording Equipment
ADAS	Agricultural Development and Advisory Service
AFCENT	Allied Forces Central Europe
AIDS	Aircraft Integrated Data System
ASDAR	Aircraft to Satellite Data Relay
ATWS	Automatic Telephone Weather Service
AUTOCOM	Automated Telecommunication Complex
AUTOPREP	Automatic Message Preparation Equipment
AUTOSAT	Automatic Satellite imagery handling system
CAA	Civil Aviation Authority
CAeM	Commission for Aeronautical Meteorology (WMO)
CBS	Commission for Basic Systems (WMO)
CCMS	Committee on the Challenge of Modern Society
CDC	Control Data Corporation
CDEM	Crop Disease Environment Monitor
CFO	Central Forecasting Office
CIMO	Commission for Instruments and Methods of Observation (WMO)
CMM	Commission for Maritime Meteorology (WMO)
COSMOS	Meteorological Office computing system
COSPAR	Committee on Space Research (ICSU)
COST	European Co-operation in Science and Technology
DALE	Digital Anemograph Logging Equipment
EC	Executive Committee (WMO)
ECMWF	European Centre for Medium Range Weather Forecasts
EEC	European Economic Community
EMEP	European Monitoring and Evaluation Programme
EPPO	European and Mediterranean Plant Protection Organization
ESA	European Space Agency
EUMETSAT	European Meteorological Satellite System
FAO	Food and Agriculture Organization (United Nations)
GOS	Global Observing System (WMO)
GTS	Global Telecommunication System (WMO)
HELIMET	Provision of meteorological services to helicopter operations (ICAO)
IAMAP	International Association of Meteorology and Atmospheric Physics (IUGG)
IASH	International Association of Scientific Hydrology (IUGG)
IBM	International Business Machines Ltd
ICAO	International Civil Aviation Organization
ICSU	International Council of Scientific Unions

IEA	International Energy Agency
IMA	Institute of Mathematics and its Applications
IMCO	Inter-Governmental Maritime Consultative Organization
IUGG	International Union of Geodesy and Geophysics (ICSU)
JASIN	Joint Air-Sea Interaction Experiment (Royal Society)
JSC	Joint Scientific Committee (WMO/ICSU)
MAFF	Ministry of Agriculture, Fisheries and Food
MCMG	Military Committee Meteorological Group (NATO)
METAG	Meteorological Advisory Group (ICAO)
MMO	Main Meteorological Office
MMS	Marine Meteorological Services
MOD(PE)	Ministry of Defence (Procurement Executive)
MOLARS	Meteorological Office Library Accessions and Retrieval System
MOLFAX	Meteorological Office Land-line Facsimile Network
MORECS	Meteorological Office Rainfall and Evaporation Calculation System
MRF	Meteorological Research Flight
NAOS	North Atlantic Ocean Stations
NASA	National Aeronautics and Space Administration, USA
NATO	North Atlantic Treaty Organization
NATS	National Air Traffic Services
NERC	Natural Environment Research Council
NOAA	National Oceanic and Atmospheric Administration, USA
OASYS	Outstation Automation System
OECD	Organization for Economic Co-operation and Development
ODAS	Ocean Data Acquisition System
OSTIV	Organisation Scientifique et Technique International du Vol a Voile
PFO	Principal Forecasting Office
PROMET	Provision of Meteorological Information Required Before and During Flight
RA VI	Regional Association VI—Europe (WMO)
SAWS	Synoptic Automatic Weather Station
SCOR	Scientific Committee on Oceanic Research (WMO)
SHAPE	Supreme Headquarters Allied Powers in Europe
SSU	Stratospheric Sounding Unit
TECIMO–II	Second Technical Conference on Instruments and Methods of Observation
TWN	Teleprinter Weather Network
UARS	Upper Atmosphere Research Satellite (NASA)
UKWMO	United Kingdom Warning and Monitoring Organization
UMIST	The University of Manchester Institute of Science and Technology
UNEP	United Nations Environment Programme
VCP	Voluntary Co-operation Programme (WMO)
VOF	Voluntary Observing Fleet
WMO	World Meteorological Organization
WWW	World Weather Watch (WMO)

Printed in England for Her Majesty's Stationery Office by Albert Gait Ltd., Castle Press, Grimsby
Dd 736035 C 10 7/83

HER MAJESTY'S STATIONERY OFFICE

Government Bookshops

49 High Holborn, London WC1V 6HB
13a Castle Street, Edinburgh EH2 3AR
Brazennose Street, Manchester M60 8AS
Southey House, Wine Street, Bristol BS1 2BQ
258 Broad Street, Birmingham B1 2HE
80 Chichester Street, Belfast BT1 4JY

Government publications are also available through booksellers

ISBN 0 11 400345 9

£12.75 net